THE AMERICAN BOYS' ENGINEERING BOOK

A. RUSSELL BOND


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LIPPINCOTT'S HOW-TO-DO-THINGS SERIES

THE AMERICAN BOYS'
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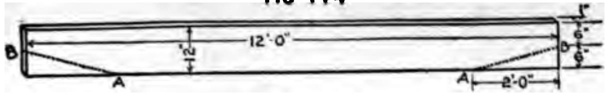


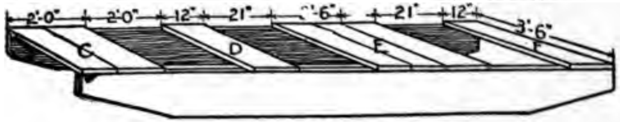
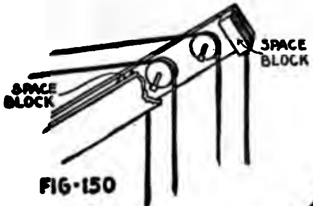


FIG-145

FIG-146



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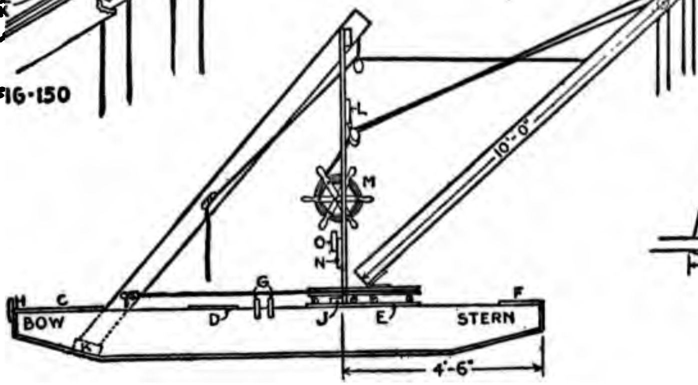

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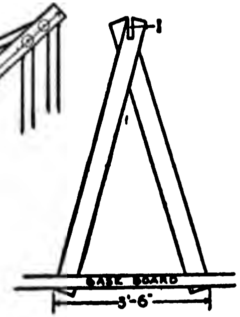

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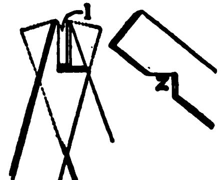

FIG-149

FIGS. 144 TO 150.—THE CONSTRUCTION OF THE SCOW

LIPPINCOTT'S HOW-TO-DO-THINGS SERIES

THE AMERICAN BOYS' ENGINEERING BOOK

BY

A. RUSSELL BOND

WITH 232 DIAGRAMS
BY EDWIN F. BAYHA

PHILADELPHIA AND LONDON
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FOREWORD

This is a play-book and not a text-book of engineering—a book full of fun, not fun at the expense of another, but the real fun and joy of making things.

It is characteristic of the real American boy to design and fashion things with his own hands. To be sure, the creative instinct is more conspicuous in some than in others, but, be it apparent or latent, the instinct is really there in every boy and needs but the proper stimulus to bring it into active evidence. It is this stimulus that the following pages seek to furnish.

Engineering is a very broad term that covers many fields of human activity. Obviously, they cannot all be treated in detail within the covers of a single volume; but the purpose of this book is to offer *practical* suggestions. In other words, the object is to develop the boy's own ingenuity and resourcefulness. The chapters on Mechanical Engineering tell how to construct a workshop and simple foot-power machine tools. This furnishes the boy with an excellent equipment, and if he will use his faculties he will become a fair or an expert mechanic. Under the subject of Surveying directions are given for the construction of simple instruments with practical illustrations of their use. They furnish the boy with the rudiments of this branch of Engineering and are calculated to stimulate his interest further.

Even a boy who is not possessed of an inventive instinct will find plenty of interest in following out the constructional

details exactly as given, but the boy with a mechanical bent will use the text principally as a foundation upon which to do his own building.

As far as possible subjects that are common to other "how-to-make" books have been avoided, and new fields are opened in which the boy may develop his mechanical and scientific bent.

In the preparation of this book the author has received many courtesies and much valuable assistance for which he takes this opportunity to express his appreciation and thanks.

The Scientific American has been drawn upon rather heavily. The method of determining true north is based upon an article that appeared in that journal some time since. The idea of using an auxiliary portrait lens for a telescope was suggested by Mr. C. Kiplinger, and the hedgehog transformer was designed by Mr. Frederick E. Ward. Both of these items are reproduced with the permission of the publishers of *The Scientific American.*

The Editor of *The Youth's Companion* very courteously gave the author permission to republish material regarding the sounding apparatus described in Chapter IV. "The War Manual," by Lt.-Col. C. C. Anderson, furnished the idea of the single-barrel raft, the straw loom and the charcoal pit. Finally the anemometer and the sunshine recorder were designed by Mr. John R. Weeks, and were taken from the Year Book of the Department of Agriculture.

A. Russell Bond

New York, August 7, 1918

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THE AMERICAN BOYS' ENGINEERING BOOK

CHAPTER I

FITTING UP THE WORKSHOP

LOCATION. TOOLS. TRESTLE. WORKBENCH TOOL RACKS.

It is more fun to make a toy than to play with it, and it is far more fun to play with a homemade contraption than with one that comes from the store. No matter how brightly painted the store thing may be, no matter how beautifully polished and set off with shiny brass and nickel, it will never be so dear to you as the thing you make in your own cellar with a kinky saw and a broken hammer, out of odds and ends found in the junk heap.

There is something decidedly lacking in the boy who does not ever lift his hand to make a thing. The men who have done the most for the progress of the world, who have given us all our wonderful inventions, are those who, as boys, loved to make things just for the joy of seeing them work. To them a junk pile was a gold mine. A gear wheel, a piece of pipe, a bolt, these are prizes that any boy would pounce upon, any boy, that is, of the creative type, and they will start his brain to inventing won-

derful machines in which these prizes will form a leading rôle. It is for such a boy, for the real boy, the one who has his pockets bulging with bits of rope, empty spools, pieces of wire, nails and screws, a broken key, a bit of shoe leather, and a thousand and one other things—it is for the boy who is hard on pockets that this book is written.

The purpose of this book is to suggest new ideas for you to work out. In it will be found many things that few boys will attempt to build and a few things that many boys will try to make exactly as described here, and that is as it should be. If this book were written for grown-ups it would be a simple matter to give directions for every one to follow, because the materials could be purchased, but there are few boys who can afford to buy just what they need in their workshop, and they have to go through the pile of old crates and boxes in the grocer's back yard for their lumber, while the other necessaries must be picked up here and there, often in the ash heaps in the neighboring vacant lot. After all, it is better for a boy not to be able to buy everything according to the book. Most of the joy of making things comes in designing them to fit the materials you have on hand. That is real invention. The boy who makes things after his own notion, instead of following the book exactly, is the one who will have the most fun, and it is quite probable that he can improve on the constructions here outlined. And so when you see something called for that you can not beg, borrow or buy, do not be discouraged, but hunt around for some other way of doing it. That will make you resourceful and ready to face

emergencies when you grow up and have to shoulder responsibilities.

Now while it is not expected that you will make everything that you see in this book, there is nothing described that you can not make, if you have the patience and materials to work with. But before you can attempt to make anything you will have to have some kind of a shop to work in.

LOCATING THE WORKSHOP

The location of the shop is a matter that should receive a great deal of careful consideration, if you have any choice at all. The commonest and about the worst place that could be selected is the cellar. It is seldom light enough, and it is almost sure to be damp, particularly in summer time, and dampness works havoc with tools. A barn or garage makes a better workshop, except that in winter time it is apt to be damp and too cold to work in. Of course the very best workshop is a room somewhere in the house where it is always dry and there is plenty of light. Sometimes a boy is allowed to fit up a room in the attic. This location has the drawback that in summer weather it is apt to be too hot, but most of the year it is ideal, particularly if the room is heated in winter. However, it is very annoying to the rest of the house to have a lot of hammering and sawing going on indoors, and the shavings and sawdust which have to be carried out every once in a while are apt to leave a trail of dirt through the house. And so it is quite probable that any proposal to fit up a

workshop in the house anywhere above the cellar will meet with a prompt veto. If the cellar is selected the greatest care must be taken with the tools. They should be kept oiled and it would be well to have a tool box, such as carpenters carry with them, in which the tools can be packed and carried up to a drier floor. If the barn or garage is used for a workshop it is much better to leave the tools in the shop in cold weather, rather than to bring them indoors, because in coming out of the cold into the warmth of the house, the moisture of the air will condense upon the cold steel and cause the tools to rust.

Tools

As for the tools a boy should have, that depends upon the pocketbook. The best plan, of course, is to buy a set, and a fair set can be purchased for about ten dollars, that will give a boy all that he could desire, with a cabinet thrown in. However, most boys have not ten dollars that they can spend. They must pick up what they can, where they can, by trade or from the second-hand man, and for them this list is made out.

The indispensable tools are as follows:

An adze-eye hammer, the common kind that has a pair of claws for pulling out nails, sometimes called a claw hammer.

A saw. There are two kinds of saws, one for cutting wood across the grain, known as a crosscut saw, and the other for cutting with the grain, known as a rip saw. It is well to have one of each, but if that is out of the question,

get a crosscut saw. It will do very well for all around work.

A plane. If you can afford to get more than one, get a block plane, or a small plane for smoothing off rough surfaces, and a jack plane which is indispensable for leveling long surfaces and truing up edges. If one plane is the only thing you can afford, by all means get the block plane, because probably the principal use you will have for a plane will be to smooth off rough, sawed surfaces, and that can be done only with the small plane.

A bit-brace. If you can afford it, get a hand drill as well, one with a crank handle at the side and with a chuck for round drill shanks. This will be found very handy for light work in metals, while for heavy work the regulation brace can be used. If you cannot buy both take the latter, as it will do very well for all around service. The best of these braces are arranged with a ratchet, so that it is possible to bore a hole in a corner where it is impossible to sweep the crank of the brace through a complete circle. With the brace it will be necessary to buy a good assortment of bits and also some drills for use in boring through brass and iron. A very convenient tool, one that will take the place of a large number of bits, is an expansion bit. This is a bit provided with a cutter that can be adjusted to bore holes of any size within the limits of the tool. Each bit is usually provided with two cutters. In one make, for instance, the smaller cutter will drill holes anywhere from 5/8 of an inch to 1 1/8 inches, while the larger cutter works from 7/8 to 1 3/4 inches in diameter.

Other indispensables are: A screwdriver, a wrench, a pair of pliers and a stone and oil-can to keep the tools in trim and always sharp. Others, which it will be very handy for you to have, are: A set of chisels, 1/4, 1/2 and 3/4 inches. Get the 1/2-inch size if you can buy only one. A draw knife will be found constantly useful. Tin shears. A set of files, including a half-round rasp for wood. A wooden mallet for hammering wood. A hack saw for cutting metal. A key hole saw or compass saw. A try square. A two-foot folding rule. A pair of dividers. A center punch. A vise.

Now that we have our tools, we can proceed to fit up our workshop. The most important piece of furniture in any workshop is the workbench, and one might suppose that this should be the first work to start upon. But it is not so easy to build a good workbench without a bench to work upon, and so our first task had better be to rig up some sort of a temporary bench on which we can do the necessary sawing, planing, etc. In any workshop a pair of trestles or horses will come in handy; sometimes they are almost indispensable. These, with a plank or two laid across them, will do for a makeshift bench until the bench is built.

Before we go any further we might as well get acquainted with the symbols for inches and feet that are used on mechanical drawings. Five inches or a half inch is written 5″ or 1/2″, while two feet and six inches is written 2′–6″. As the foot mark and the inch mark are very much alike, a careless draftsman might put down one for

the other. To avoid this confusion, all measures over two feet are always expressed in feet and inches; for instance, four feet would not be written 4′, because it might be mistaken for 4″, instead it is written 4′–0″. Figures under two feet are always expressed in inches; for instance, one foot and nine inches would be 21″ and not 1′ 9″.

How to Make a Trestle

The standard trestle is 4 feet long and 2 feet high, and it has for the body a stick 3 inches wide and 4 inches deep. The legs are cut out of 1-inch stuff, 4 inches wide by 26 inches long. They are notched into the body, and this is the hardest work of the whole job, because the leg must be set on a slant crosswise as well as lengthwise of the trestle. Perhaps the simplest way of getting the right angle for the notches is to nail the legs to the body temporarily with a single nail right through the center line of the leg and of the body, and 6 inches from the end of the body. A plumb line hung from the end of the body will show just how far the legs should be slanted. This done, mark the body with a sharp pencil or a chisel along the sides of the leg, to indicate where the notches are to be cut. Now the legs may be taken off the body and saw cuts made along these marks. The notches must taper from nothing at the bottom of the body to a depth of 1 inch at the top, as shown in Fig. 2. It is best to mark out this depth on the top of the body so as to be sure that the saw cuts do not run too deep. With a chisel the wood is cut out between the saw cuts and then the legs are fitted into the notches and nailed fast.

The legs are braced apart by means of pieces of board 6 or 8 inches wide, which are sawed off flush after they have been nailed fast (see Fig. 3). The legs, in turn, will have to be trimmed off flush with the top of the body and

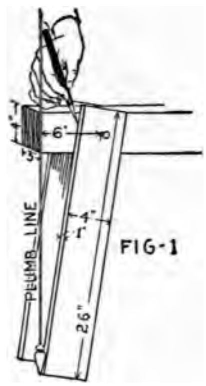
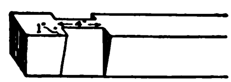


FIG-1

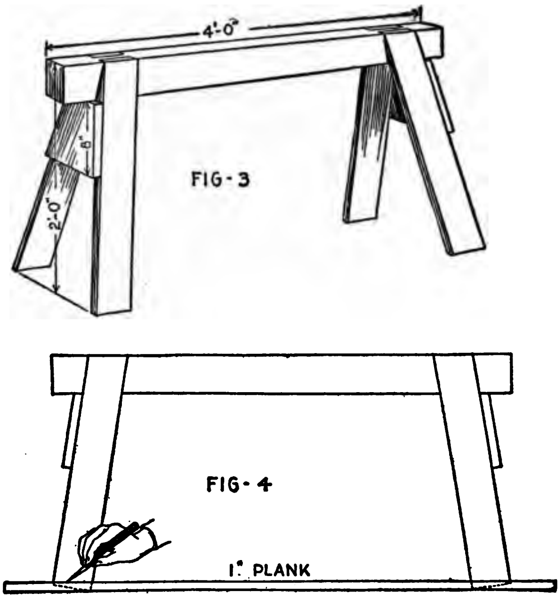
FIG-2



FIGS. 1 and 2.—Planning the trestle

their lower ends will have to be cut to rest flat on the floor. A simple way of doing this is to set up the trestle on its legs, on a level floor, putting a chip or two under this or that leg until the trestle stands level. Then, laying a 1-inch plank on the floor against the legs, mark them with a pencil drawn along the board (Fig. 4). If the legs are sawed off carefully along the pencil line, the trestle will stand firmly without teetering. The finished trestle is shown in Fig. 3.

A couple of solid planks should be nailed across two trestles and we have a workbench, rather low to be sure, but good enough until the permanent bench is built. The trestles must not be set very far apart or the planks sup-



FIGS. 3. and 4.—Completing the trestle

ported by them will sag, especially when any planing is being done. A small block nailed to one of the planks near the end will provide a stop for the boards or timbers that are to be planed. Boards may be supported on edge for planing by fitting them between uprights nailed to the trestle bodies.

The Workbench

Now we can proceed with the building of the permanent workbench. Of course the average boy will have to make the bench out of such materials as he can lay hold of. But with the following plans of how a bench should be made, he can introduce such changes as will suit his pocket book or the stuff he has to work with.

The height of a man-sized bench is 33 inches and its length is 12 feet, but a boy will hardly want one quite so large. A length of 10 feet, or even 8 feet, will be enough, and a height of 30 inches will probably be about right, although that will depend upon the size of the boy.

Cut the legs or posts of the bench out of the same-sized stuff as was used for the body of the trestle, namely, 3 by 4. It may be more convenient to use 2 by 4, but the bench will not be quite so solid and a firm bench is very important if you are going to turn out good work. The post at the forward-left-hand corner of the bench is to carry the vise, and so it would be better to use a wider and heavier timber here—say a 3 by 6 piece.

Saw off the legs to a length of 28 inches. Two 1¼-inch holes, 2 inches apart, should be bored through the heavier leg near the bottom, and the wood between the holes should be cut out with a chisel, so as to form the mortise for the heel of the vise (see Fig. 5). Out of a board 10 or 12 inches wide cut two spacers 22 inches long, and use these as the end pieces of the bench to connect the upper ends of the legs. The front and rear board 12 inches wide are now nailed to the legs or posts, letting them extend about

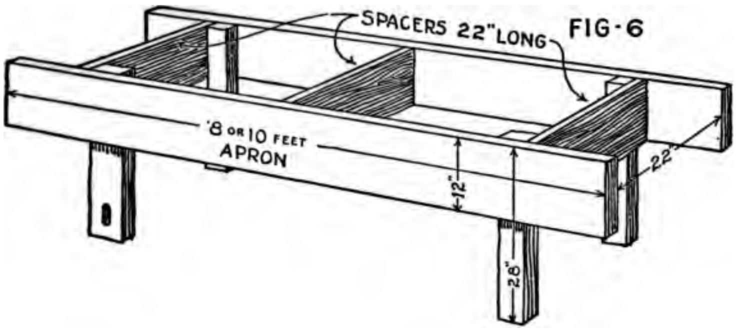


FIG-6

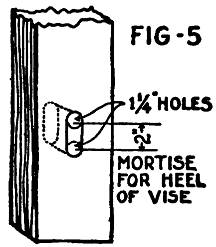


FIG-5

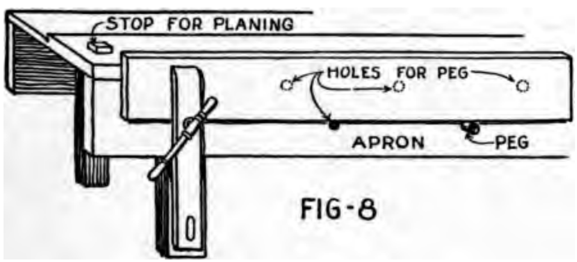


FIG-8

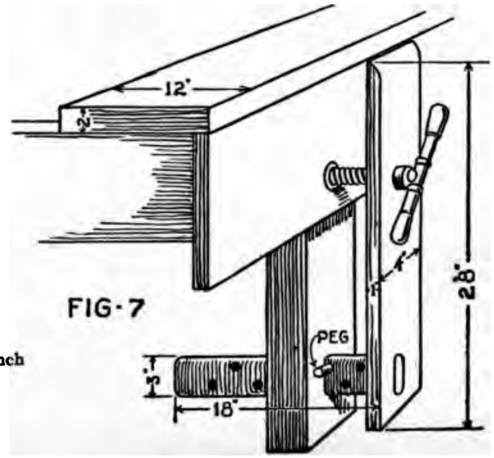


FIG-7

FIGS. 5 TO 8.—Details of the workbench

10 or 12 inches beyond the legs (Fig. 6). The board should run the full length of the bench, whatever size it may be decided to make it. If the bench is to be over 8 feet long, it would be well to put in a third spacer midway between the other two.

For the top of the bench use two planks, 12 inches wide and at least 1 inch thick. Two-inch planks would make a better bench, and if possible at least the forward plank should be of 2-inch stuff. By all means use hard wood for this plank.

The vise jaw is made of hard wood 2 inches thick, 4 inches wide and 28 inches long. In this plank, near the bottom, a mortise is cut, smaller than that in the 3 by 6 bench post, so that while the vise guide or heel has to be driven tightly into the mortise of the vise jaw, it will fit freely into the mortise of the bench post. This guide measures 1 by 3 inches and is 18 inches long (See Fig. 7). It must have its edges rounded to pass smoothly into the slot in the bench post, and it is fastened to the vise jaw by driving nails into it on a slant through the face of the jaw. Several 1-inch holes are drilled in the guide and a peg is provided to fit them. When a large piece is to be held in the vise, the guide is pulled out correspondingly and the peg is inserted to keep it from sliding in again. The screw and nut for the vise will have to be bought at a hardware store.

If the vise is to be used for holding one end of a long board, while planing it or doing any other work, some means must be provided to hold up the other end, and so holes are usually bored in the "apron" or front board of

the bench, and a wooden peg inserted into the proper hole will provide the necessary rest. There should be two rows of holes, one above the other, for narrow and wide boards.

One more detail and the bench is completed. A square hole is cut through the forward top plank of the bench. This is done by boring holes in the corners of the square and cutting out the wood between them with a chisel. The hole should be about 2 inches square. Then a block of hard wood, just big enough for a driving fit, is hammered into the hole with a mallet. This block may be used as a stop (Fig. 8) against which a board may be abutted when the face of the board is being planed. With a tap of the mallet the block may be adjusted to any thickness of board, and when it is not in use it may be driven down flush with the surface of the bench.

Tool Racks

A workshop is not complete unless it is fitted up with racks to hold the tools. A shelf should be built on the wall just above the bench on which various tools can be laid when they are not in use. Of course, the ideal thing is a chest of drawers in which the tools can be kept out of the dust and moisture, but it is quite a task to build a chest of drawers, and not many boys will be able to get hold of such a piece of furniture, and so a shelf will have to do for our workshop. On this shelf a place must be assigned for each tool and the tool must always be put back in place. That is the only way to keep track of things and have the tools where you can lay your hands on them just when you

need them. Holes can be bored in the shelf to receive the drills, bits, chisels, pliers, and such tools, and nails should be driven in the wall of the shop on which to hang the saws, bit-brace, etc. The hammer, the draw knife, and even chisels can each be hung between two nails. But it is hardly necessary to tell a boy just how to arrange his tools. That is a matter that he can attend to for himself; the main thing to remember is that there must be a place for each tool and never to leave the workshop without having each tool in its place.

CHAPTER II

MACHINE TOOLS FOR THE WORKSHOP

FOOTPOWER GRINDER. SCROLL SAW ATTACHMENT. DRILL PRESS. SPRING BOARD LATHE. SPEED LATHE. THE FORGE.

WHEN a boy tries to fashion things out of wood or metal, he is handicapped by the lack of certain machines which the professional or grown-up amateur has in his workshop. Such tools are so expensive that very few boys can afford to have them, but there is no reason why you should not make your own machines. They will be crude, it is true, but nevertheless fairly good work can be done with them, if they are well constructed, and certainly they will be found well worth the time expended in building them.

When we think of fitting up a model workshop, one of the first things that comes to mind is a good screw-cutting lathe. The lathe certainly is the king of all tools, but there is another machine, not half so showy, one that cannot compare with the lathe in the variety of work that it will do, but a tool which is far more important, because even the lathe will not do really good work without its help. That tool is the grinder, the machine that keeps tools sharp, and unless the tools are sharp, good workmanship is impossible. They say that a poor workman blames his tools; and well he may, for the chances are his tools are not sharp and they really would not turn out good work

even in the hands of a good workman. The first thing that a good workman does is to examine his tools and see that they are really in good condition; then he makes it a point to watch the cutting edges and keep them always sharp by frequent use of the emery wheel, or grindstone and the oilstone. One of the first things, therefore, for the amateur to do is to buy a good oilstone and make a grinder, and then above all learn how to use them.

The Footpower Grinder

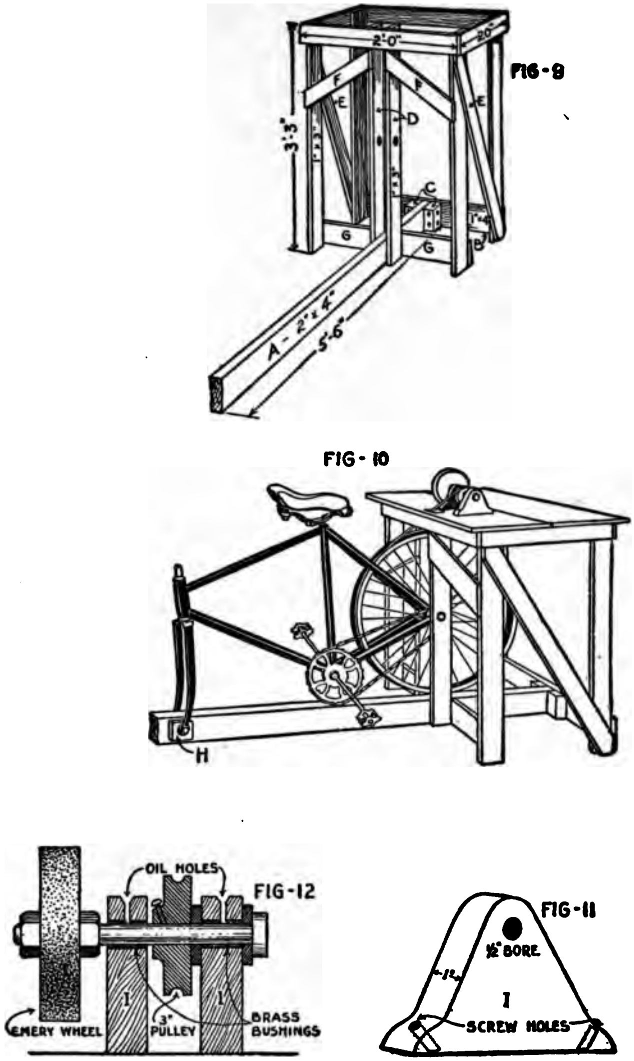
Unless you have a lathe and are skilled in the working of metals, it is liable to be a difficult task to build even the simple mechanism of a grinder, but if you are resourceful, you will find something that will help you to do without lathe work. Somewhere around the house there is sure to be an old bicycle that can be pressed into service. If so, fully half of the machine is already made. Take off the front wheel and the tire of the rear wheel, then turn the saddle around so that it faces the rear wheel, and tip its nose down as far as it will go. This will serve as our power plant.

To make the table on which the grindstone is to be mounted, cut out four legs, 3 feet long, 3 inches wide and 1 inch thick. Frame these together at the top, as indicated in Fig. 9, with 1 by 3-inch strips, making a frame 2 feet wide and 20 inches deep. Get a 2 by 4 inch stick or scantling A and lay it on the floor between the legs of the table. This stick will have to be about 5 feet 6 inches long. A strip of wood B, 4 inches wide, connects the rear legs of the

table and the end of the scantling is nailed to this strip. Nails driven into the end of a stick of wood parallel to the grain of the wood will not hold securely. The only way to make them hold is to drive them in on a slant. It might even be advisable to nail blocks, C, to the sides of the stick with the grain running up and down, then nails can be driven through the brace B into these blocks C, as shown in Fig. 9. At the forward end of the table two boards, D, 3 inches wide and 1 inch thick, are nailed at the bottom to the scantling, while at the top they are fastened firmly to the front frame piece. Diagonal braces, E,E, and F,F, will make the table firmer. At the bottom these uprights, D, are connected to the front legs by means of short braces, G, on either side of the scantling. The table top is now nailed on. It should overhang the frame about 3 inches on each side and should measure 2 feet 6 inches wide by 2 feet deep.

The bicycle is now made fast to the table. Two holes are bored in the uprights D 17 inches above the floor. The uprights are now sprung apart and the rear wheel of the bicycle is introduced between them with the nuts on the axle fitting into the two holes just referred to. This done, the front forks are placed astride the scantling and a hole is bored in the stick in register with the axle holes in the fork. The fork is then made fast to the stick with a good-sized bolt. Wooden spacers, H, will be needed to make a snug fit.

The grinder head can be bought with pulley and grindstone or emery wheel at any hardware store. As this is a



FIGS. 9 TO 12.—Foot-power grinder made out of an old bicycle

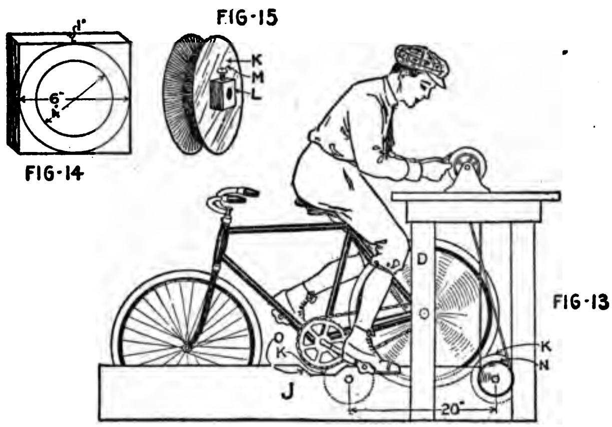
very important part of the workshop outfit, it would be advisable to buy it instead of making it, if the money can by any means be spared. Of course the emery wheel will have to be bought. Then all that has to be done is to fasten the head down to the table, with the pulley wheel directly over the bicycle wheel, bore two holes in the table top and through these holes connect the two wheels with a leather or canvas belt. The grinder will then be ready for service. To use the machine, sit on the saddle and work the pedals so that the emery wheel will turn toward you.

If the grinder head cannot be bought we shall have to make one. Get a ½-inch bolt about 6 inches long with at least 2 inches of it threaded; also two nuts and a couple of washers. This will be the shaft on which the grindstone or emery wheel can be clamped between the two nuts. A 3-inch pulley wheel will have to be bought. Get one with a half-inch bore to fit upon the bolt. Two standards I, of hard wood, will have to be made for the bolt to turn in. These should be of about the shape shown in Fig. 11. The height of the standards will depend upon the size of the emery wheel that is to be used. Bore a hole in each standard near the top for the bolt to turn in. These bearing holes must be exactly in register and so the two standards should be clamped together or fastened together with a couple of nails and then a hole can be bored right through both standards at once. Get a couple of pieces of brass tubing just large enough to fit freely upon the bolt, and use these as bushings for the bearing holes in the stand-

ards. The bearing holes will have to be bored with an expansion bit so that the bushings will just fit into them snugly with a driving fit. Try a few holes in a spare piece of wood until the expansion bit has been adjusted to the right size. Do not drive the bushings in with a hammer, use a wooden mallet or at least a block of wood between the hammer and the brass, to keep from burring the edge of the bushing. An oil hole will have to be bored down through the top of each standard. Use a 1/8-inch drill and bore right through the bushings. Smooth off the burr on the inside of the bushing with a round file or a piece of emery cloth wrapped around a stick. Fasten the two standards I to the table by means of long screws run in on a slant. Then assemble the grinder as shown in Fig. 12 with a washer between the head of the bolt and the right hand standard and another washer between the same standard and the pulley. Move the pulley up against this standard, but not too snugly, and then make it fast by tightening up the set screw. This will keep the bolt from playing endwise. The emery wheel can now be clamped between the two nuts as shown. Of course, in setting up the standards, we must bear in mind that the pulley wheel must lie directly over the bicycle wheel. After dropping a little oil into each oil hole, our grinder will be ready for service.

In designing this grinder we have taken it for granted that an old bicycle can be found somewhere. Every boy may not be so lucky. There is really no reason why a good bicycle should not be used. The machine is not injured in any way and it can always be reassembled and be

put back on the road. But it is certainly a big bother to take off the front wheel and particularly the rear tire every time you want to do a little grinding, because the tire has to be cemented on the rim when it is put on again. Unless an old wheel is to be had, it is better to rig up the grinder to be run by a bicycle that does not have to be altered materially for the purpose. Fig. 13 shows how this may



FIGS. 13 TO 15.—Making a grinder without dismantling the bicycle

be done. The same table is used and the same grinder head as just described, but the uprights are set a little farther apart, so that the rear wheel will fit easily between them, and hold the bicycle from toppling over, and instead of a 2 by 4 scantling two ¾-inch boards J, 8 or 10 inches wide, are used. These are spaced apart sufficiently to admit a pair of pulleys 6 inches in diameter. Each pulley is made out of two pieces of board nailed together with the

grain of one piece running at right angles to the grain of the other. Take a piece of straight-grained white pine 1 inch thick and 6 inches square. Draw two circles on each piece, one 6 inches in diameter and the other 4 inches (Fig. 14). Saw off the corners of the board that project beyond the 6-inch circle and then with a draw knife trim the edge of the board to a true circle. This done, taper the edge with the draw knife down to the 4-inch circle. Nail two such boards together with the 4-inch sides touching and you will have a V-grooved pulley, K, Fig. 15. A block of hard wood, L, 1½ inches square and 1 inch thick, should be nailed securely to the pulley at the center, to provide a hub. Through this bore a ½-inch hole for the shaft of the pulley. At right angles to this bore a small hole is bored to receive a set-screw, M, which in this case is a wood screw with the point filed off. In order to make the set-screw hold firmly file a flat spot upon the shaft that is going to carry the pulley just at the place where the set-screw is going to bear against it. For the pulley shafts use a pair of ½-inch bolts mounted to turn in holes in the boards J, the bearing holes being bushed with brass tubing as in the grinder head. These bearings will have to be 20 inches apart and equally spaced on opposite sides of the uprights D. On these pulleys the rear wheel of the bicycle is to rest. The outer pulley is merely an idler and its bolt need not be more than 6 inches long, but the inner pulley will have to carry another pulley, N, on the same shaft and it must be at least 8 inches long. In fact, it may be difficult to get so

long a bolt of that diameter, and a larger size will have to be used, or maybe a piece of ordinary round iron may be found that will serve as well. The grinder head will have to be set with its pulley directly over the pulley N and the two will have to be connected with a belt. If the bicycle is equipped with a coaster brake so that it cannot be run backward, the belt will have to be given a half twist which will make the grinder wheel turn in the right direction.

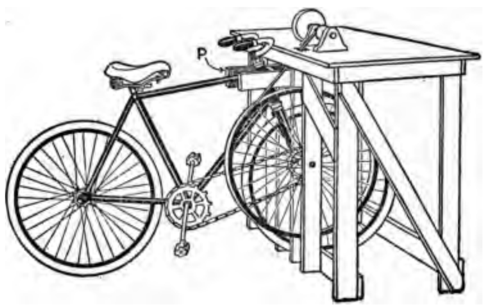


FIG. 16.—A still better plan

Now to use this grinder all you need to do is to back the bicycle up to the table, slip the rear wheel between the two uprights and rest it upon the pulleys; then turn the seat the other way around, jump on and begin to pedal. The pieces J will have to be notched as at O, Fig. 13, for the pedal hub to rest in.

If an old rear wheel with hub and sprocket intact is to be found, still another scheme can be employed. There must be three uprights, D. Mount the wheel between two of the uprights D and connect the wheel by means of a belt with the grinder pulley, Fig. 16. Then fasten two stops, P, be-

tween the other two uprights and the underside of the table top, that will seize the frame of the bicycle and hold it firmly. Uncouple the sprocket chain and run it from the pedal sprocket to the sprocket of the old wheel. The stop, P, that fits under the table should be set to hold the bicycle off far enough to keep this chain reasonably taut. With this arrangement you will find that the pedalling is much more comfortable and natural than in the plan just outlined, and the drive will be much more positive, while the bother of changing the chain will hardly be more irksome than that of turning the seat around and adjusting it for use in reverse position. The only disadvantage is that you will have to back pedal in order to make the emery wheel turn toward you. A block will have to be set up in front of the emery wheel for the tool to rest on while it is being ground.

A Scroll Saw Attachment for the Grinders

Having finished our grinder we can convert it by means of a simple attachment into a scroll saw. Figs. 17 to 20 show how the attachment may be constructed. We are going to use the grindstone spindle for the power shaft of the scroll saw, and so we must remove the emery wheel or grindstone, putting in its place a pulley about 3 inches in diameter. The bore of the pulley should be countersunk so that the nut which holds it on will be flush with its outer face. In the face of the pulley a screw is inserted at about an inch from the center. A long screw should be used, so that it will have a good hold in the pulley and will yet leave about an inch projecting from the face of the

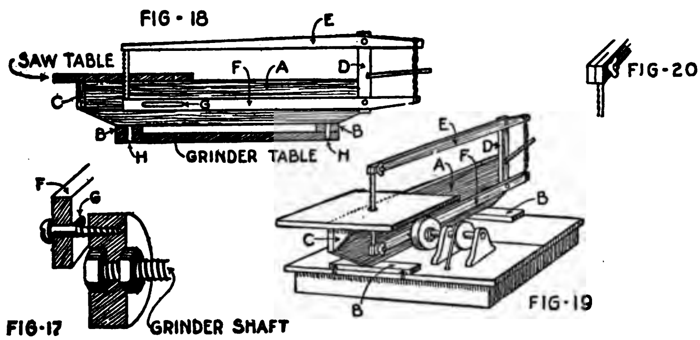
pulley. This screw is to work in a slot in the lower arm of the saw frame.

The table of the saw may be made of a couple of boards joined to make a 14-inch square. In the center of this table a hole is bored about 1/8 inch in diameter. This table will have to be supported far enough above the grinder table to clear the grinder pulley, which means that it should be raised about 6 inches. Take a board 1 inch thick, 5 inches wide and 30 inches long. This board is shown at A in Figs. 18 and 19. The board is to be set on edge and to hold it in this position it is provided with a couple of feet B near each end. These feet are formed of strips of wood 2 inches wide, an inch thick and a foot long. They should be spaced apart about 16 inches so that they will rest on the grinder table flush with the rear and front edges of the table. For the sake of appearances the board A, where it projects beyond the feet B, may be cut off on a slant as shown in the drawing. The saw table is secured to the upper edge of the board A, with the hole in the center of the table 6 inches from the end of the board and 1 1/2 inches to the right of the board as viewed from the front. An angle brace, C, between the table and the board will help to make the structure substantial.

At the opposite end of the board, a 1 by 2 by 8 inch strip of wood is nailed fast, as indicated at D. This piece is to carry the bearings of the upper and lower saw frame members E and F. These should be 30 inches long, 2 inches wide and 3/4 of an inch thick. The member E may be tapered to a width of 3/4 of an inch, at the point where the

saw is to be applied. The member F, however, should not be tapered, because it is to have a slot in it at G. The members are pivoted to the piece D, 6 inches apart and 6 inches from the rear end, the member F being set on edge and the member E on its side.

To secure the saw in the frame a cut is made in the front end of the pieces E and F to a depth of 1 inch, and then by means of a small screw and a wing nut (Fig. 20)



FIGS. 17 TO 20.—Scroll saw attachment for the grinder

the slot may be closed upon the saw, clamping it tightly. To provide the necessary tension on the saw, the rear ends may be connected by a turnbuckle. To save the expense of a turnbuckle, however, a tourniquet can be used. The rear ends of the members E and F are notched to receive a band of heavy twine. A small lever is inserted in the band and then turned so as to twist the twine and bring the desired tension on the saw blade. The tourniquet may be held from untwisting by letting the lever bear against the piece D.

The saw attachment will have to be adjusted to the grinder table so that the slot G will engage the screw in the pulley on the grinder spindle (Fig. 17). Once this adjustment has been made, holes should be bored through the feet B into the grinder table. By using an expansion bit, the holes may be made a shade smaller in the feet B than in the grinder table. Make the holes in feet B a driving fit for a set of pins H, Fig. 18. As soon as the point of the bit has penetrated into the grinder table, enlarge the sweep of the bit slightly by moving the cutter out, so that when pins are driven into the holes they will remain tightly wedged in the feet B, and yet will enter the grinder table freely. These pins will serve to position the scroll saw attachment and then it can be made fast by means of a hook and eye at each corner. The attachment can be readily applied to or removed from the grinder and with it curved forms may be sawed out as desired. It will be found a useful tool for the work that is to be taken up farther on in this book.

A Simple Drill Press

Mention was made in the last chapter of drilling or boring through brass. Strange as it may seem, there are many boys who think that the only material they can work with their tools is wood, and that when it comes to doing anything with brass or iron or steel, they must turn the work over to a machinist or a blacksmith. It is really a very simple matter to bore holes in metals, unless they have been hardened. The ordinary twist drill and a common hand-brace will do the trick. Even steel will yield to

the drill, but the job will be a long and tiresome one, because a heavy pressure will have to be maintained on the brace. The task will be very much simplified if a bit of apparatus is built to hold the brace and keep a constant pressure upon it.

It is always difficult to bore a straight hole with the ordinary hand brace, because the eye can only see the drill from one side. Suppose you are trying to drill a horizontal hole; if you hold the brace against the breast you can look down upon the drill and keep it in line from that direction, but you will have no way of telling whether the drill is slanting upward or downward. By means of the apparatus we are about to build, this difficulty can be overcome very easily.

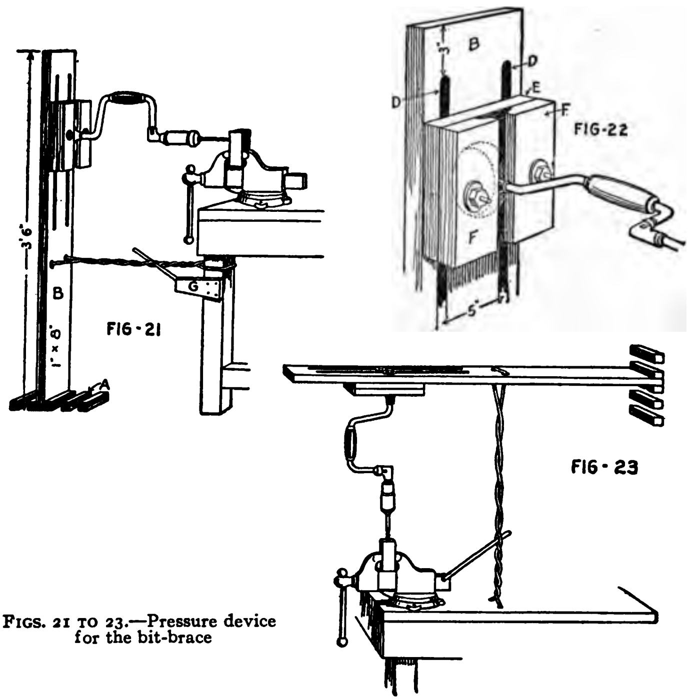
If metals are to be drilled they should be held in a steel vise, and we shall assume that such a vise has been purchased and fastened to one end of the workbench. On the floor directly in front of the vise a number of cleats A, Fig. 21, should be nailed. These cleats must be strips of wood 1 inch square and 8 inches long. Set the first cleat about a foot from the leg of the bench and the others an inch apart, back of this. Take a 1-inch board 8 inches wide and about 3 feet 6 inches long. In this board B, Fig. 22, cut two slots, D, ½ inch wide and 18 inches long. These slots should come within 3 inches of the upper end of the board, and they should be spaced about 5 inches apart. The slots are cut by boring a hole at each end and sawing out the wood between them with a keyhole saw or compass saw. It will probably be necessary to cut two

overlapping holes at the start of the slot, so as to make room for the saw.

On this board we are going to mount a holder for the brace. Take a piece of 1-inch board, 8 inches square (E, Fig. 22) and in the center of it cut a hole just large enough to receive the head of the brace. A circular hole sawed out with a compass saw, or a scroll saw, would make a neater job, but it is not necessary for the hole to be round. A square hole can be cut much more easily by boring a hole in each corner of the square and making straight cuts of the saw from one hole to the other. Two more pieces, F, will be necessary, each 6 inches long and 3½ inches wide. The inner edges of these pieces may be bevelled off slightly as indicated in the drawing. When these pieces are laid on the piece E, flush with the edges of the latter, there will be a space of about 1 inch between them. Now with the clamps F in place upon the piece E, two bolt holes will have to be drilled through the holder just far enough apart to register with the slots in the board B. The holder may then be clamped to the board by means of ½-inch bolts about 4 inches long as shown. A broad washer on each bolt head will keep it from slipping through the slots in the board, and a washer should be placed under the nut on each bolt to keep it from digging into the clamp. By taking off one of the clamps or by loosening both of the bolts, the head of the brace can be slipped into the hole in the carrier. Then on tightening up the nuts, not only will the clamps close tightly upon the head of the brace, but the entire holder will be clamped firmly to the board. It will be found much more convenient to use wing-nuts on the bolts

so that they can be tightened up with thumb and finger, in place of using the wrench.

The foot of the board is now rested on the floor between a pair of the cleats, A, and, before the nuts are tightened,



FIGS. 21 TO 23.—Pressure device for the bit-brace

the holder is adjusted to the proper level to bring the point of the drill in line with the work held in the vise. When drilling metal, the hole must always be started by denting the metal with a center-punch. In this center the point of the drill is rested while the holder, after it has been clamped

to the board B, is carefully adjusted up or down, with a light tap of the mallet, until the drill lies truly horizontal. The board should be set between the cleats that will bring it to a vertical position.

To bring the necessary pressure upon the drill, use a tourniquet. Take a piece of stout braided clothes line. Pass it around a leg of the bench directly under the vise and through a pair of holes in the board B, tying the two ends together at this point. This rope should be placed low enough to clear the handle of the vise easily when the latter is in its lowest position, and it should be slack enough to let the board be moved out to the last cleat or far enough to accommodate the longest bit or drill that is liable to be used. Now take a stick of wood and insert it between the lines of rope, near the bench, and with it twist the rope until it draws the brace tightly against the work. The stick may be caught against a stop G, on the leg of the table, to keep the rope from untwisting.

When using this device, lean against the board to keep it from swinging to one side or the other. As the drilling proceeds, give the rope a turn or two, now and then, to keep up the necessary pressure. Of course, as the drill bores into the work, the board will swing forward, throwing the brace a little out of alignment, but the movement will be so slight that we need not pay any attention to it unless the hole is a deep one, when the trouble can be rectified by adjusting the holder now and then with a tap of the mallet. With this simple homemade drill press, metals of all kinds can be cut through very quickly. Do not forget that

in boring through cast iron or steel the drill must be literally bathed in oil all the time. You can not give it too much oil. For the softer metals, it will not be necessary to use the rope. By merely leaning against the board enough pressure will be developed to do the work. Far more pressure, with much less discomfort or exertion, can be applied against the board than against the bare head of the brace.

Sometimes it is necessary to bore holes vertically, because the work cannot be turned around to such a position as to permit of horizontal boring. For such work the same apparatus may be used as in Fig. 23. The foot of the board is rested on one of several cleats nailed to the wall back of the bench, and it lies horizontally over the table with the holder directly above the vise. The rope with which the pressure is applied passes through a pair of holes in the top of the table. This is in some respects a better arrangement, because when drilling downward it is easier to keep oil in the hole.

A Spring-Board Lathe

We now come to the prince of machines—the lathe. Long before Christ was born the Egyptians used lathes to turn wood. Their lathes were very different from the machines that are now commonly seen in our workshops. They were the very simplest of machines, such as any boy could make, and yet with them a great deal of very intricate turning was done. In fact, lathes of this type are still in use in the Orient, and the writer has seen heavy newel posts of hard wood turned up in elaborate patterns with a lathe of this sort, hastily rigged up by the carpenter.

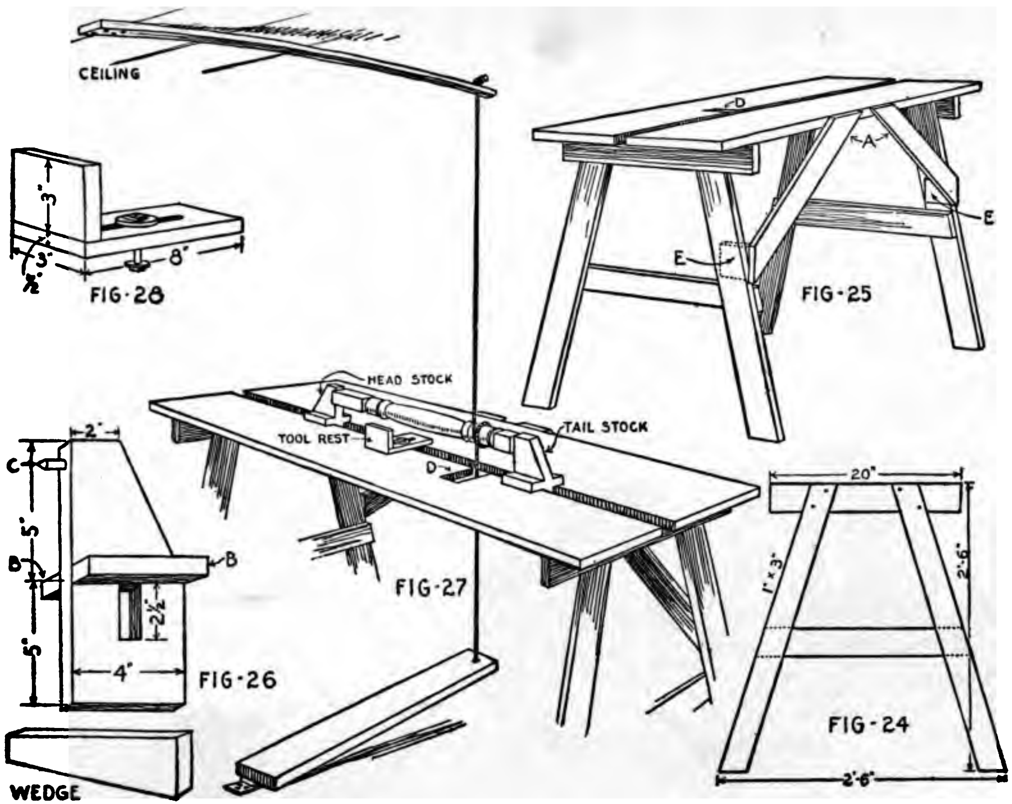
First a table or lathe bed is needed, and this will take longer to build than all the rest of the lathe. Make two frames of the size and shape given in Fig. 24. Set these up about 3 feet apart and nail two boards across them, to form the top of the bench. The boards should be 1 inch thick, 10 inches wide and 4 feet long, and a space of 1 inch should be left between them. To steady the bench and keep it from teetering endwise, two diagonal braces A, Fig. 25, must be nailed from the legs to the rear edge of the bench top. A block of wood E, with the grain running up and down, may be nailed to each of the table legs, and the braces may be nailed to these blocks. After they have been nailed fast, the projecting corners of the braces may be sawed off flush with the legs and with the bench top.

For the headstock and the tailstock of the lathe, cut out two pieces of board to the form shown in Fig. 26. Hard wood, such as oak, is the best material for these pieces. In each piece cut a slot 1 inch wide and 2½ inches long, and just above the slot nail two pieces, 1 inch square, one on each face of the board, to form shoulders B. In the edge of each piece, 4 inches above the slot, drive a heavy nail, letting the head project about half an inch. Then file the head off to a point, C, Fig. 26. A screw might be used in place of the nail, because it will have a larger body, but it will have to be screwed in very tightly to keep it from working loose when the lathe is in use. It is most important that the nail, or center, as a machinist would call it, be at exactly the same level in the two pieces when they are set up in the lathe. The slotted shanks of the head-

stock and tailstock are meant to project between the two boards of the table top, and they are clamped in place by driving wedges into the slots. In order to get the centers at exactly the same level, it would be advisable not to nail on the shoulder pieces B of the tailstock until after the head-stock is clamped in place; then after adjusting the tail center so that it is exactly on a level with the head center, the shoulder pieces may be nailed on to hold it at this level. As for the wedges, they are merely pieces of hard wood 1 inch thick, 6 inches long and tapering from 1 inch to 2 inches.

The rest of the lathe consists merely of a pedal, a spring board or pole, and a piece of rope. In the Orient, the pole usually consists of a green sapling, but we can use a strip of 1 by 2 inch wood that is straight grained and has plenty of spring in it. It should be about 5 or 6 feet long. It must be nailed to the ceiling at one end with its free end directly over the center of the lathebed. To this free end the rope is tied. The rope hangs down through the slot in the table and at its lower end is fastened to the pedal. The pedal is a board about 3 feet long and 6 inches wide.

In using this lathe, the work that is to be turned has a center punched in each end, then a turn of the rope is taken around it and it is centered between the nail points of the head and tail stocks. This should raise the rope end of the pedal a foot or more off the floor. Of course, the larger the work, the higher the pedal will be raised. The matter can be adjusted by taking up a little rope for work of small diameter and letting out a little for very large pieces. How-



FIGS. 24 TO 28.—Construction of the spring-board lathe

ever, a variation of 6 inches or so will not matter much. Now on pressing down the pedal, the rope will make the work turn on its centers, and on releasing the pedal the spring board will turn the work back again, raising the pedal for the next stroke. When taking the turn of rope around the work, be sure that you make it in such a direction that on the downward stroke of the pedal it will turn toward you. It will be necessary to cut a notch, D, Fig. 27, in the inner edge of the front board of the bench, for the rope to pass through when large pieces are being turned. This notch should be about 2 inches wide and 4 inches long.

One more detail is needed, and then we shall be ready to go to work with our primitive lathe. There must be a tool holder to rest our chisels upon. Of course a block of wood that will bring the chisel point just above the center will do, but a more satisfactory tool rest can be made as shown in Fig. 28. Take a strip of wood 3 inches wide and 8 inches long. Cut a slot through it ½ inch wide and 5 inches long. Nail it to the bottom of a piece of wood 1 inch thick, 3 inches high and 3 inches wide. Then get a ½-inch bolt 2½ inches long, with nut and two broad washers. Pass the bolt through the slot in the tool rest and the slot of the table top, with one of the washers under the head of the bolt and the other bearing against the under side of the bench top; then with the nut the tool rest may be clamped in place. Of course a thumb nut, or wing nut, if one is to be had, will prove much more serviceable. The tool rest can be moved in or out just as far as necessary and with the wing nut it may be quickly secured. With

this form of lathe the cutting is done only on the down stroke of the pedal. Be sure to keep the point of the chisel slightly above the center of the work that is being turned.

Construction of a Speed Lathe

If you are ambitious and wish to build a lathe that looks more like the modern kind, the following plans may prove serviceable.

Before starting to work on this lathe you must get hold of a large pulley wheel somewhere. It must be quite heavy, because it is to serve as a fly wheel, as well as a driving pulley. A junk dealer will probably have just the thing—a wheel about 2 feet in diameter with a 2-inch face. In the hub of the wheel there should be a set-screw to fasten the wheel securely upon the crank shaft. For the crank shaft you will have to use your forge (see page 59); or if you haven't a forge, call upon a blacksmith and get him to bend a rod to the dimensions given in Fig 29. The rod should be about ½ inch in diameter, and you will see from the drawing that it must be at least 4 feet 9 inches long before bending. While he is at it, get the blacksmith to make you a couple of straps, A, Fig. 30. One end of each strap should be bent around the 3-foot part of the crank shaft and be riveted back upon itself so that it circles the shaft freely, but not too loosely. The strap should be given a twist of a quarter of a turn and should have a hole in the free end by which it can be fastened to the treadle.

The fly wheel B is to be mounted on the shaft C (Fig. 31), and the chances are that the bore of the wheel will be

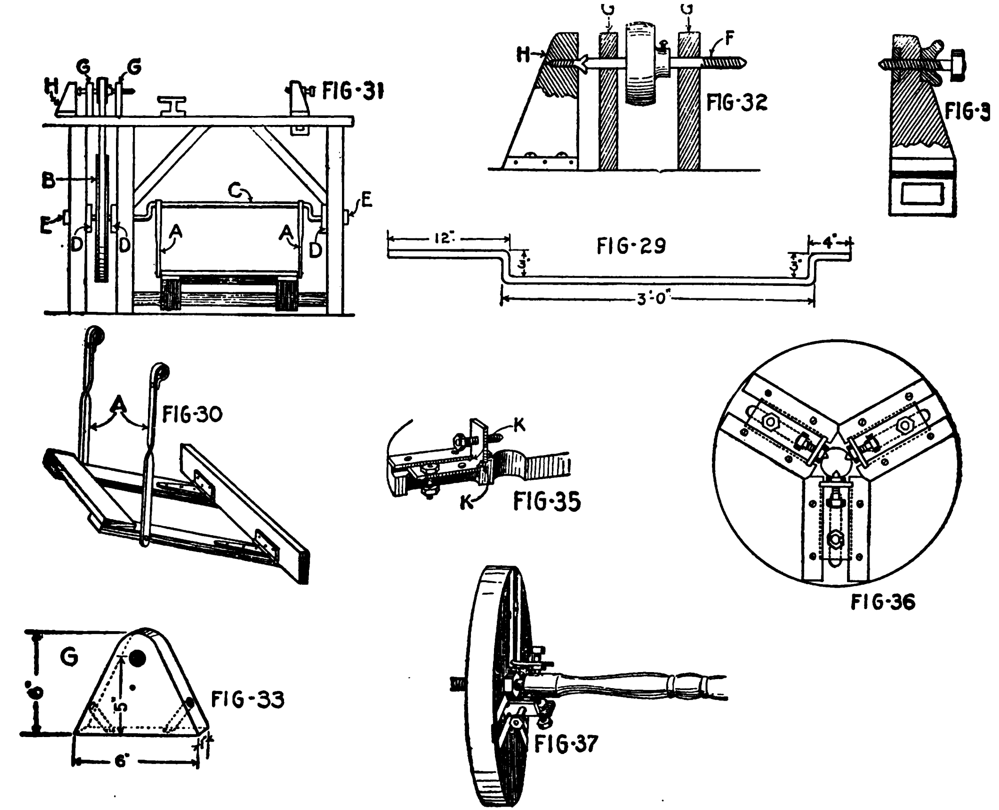
much larger than the diameter of the crank shaft. This being the case, the wheel will have to be bushed. Take a block of hard wood and shave it down to a driving fit in the bore. After it has been driven in with a mallet, bore a hole in it just large enough to fit snugly upon the shaft. Be very careful to have this hole squarely in the center of the wheel. Extend the set-screw hole through the bushing with a drill that will just enter the hole in the pulley without injuring the threads in it. Then get a set-screw long enough to reach through the bushing. When this is screwed in, it will cut its own threads through the wood.

We can now build the lathe bed in much the same way as we made the table for the spring-board lathe, except that we shall have to have three sets of leg frames instead of two. Two at the left-hand side of the bench will have to be set up with a space of but 6 inches between them, while the third will have to be placed about 3 feet 2 inches to the right. As in the spring-board lathe, the bench top will consist of two planks spaced an inch apart. These planks will have to be 5 feet long so as to overhang at least 5 inches at the left-hand end of the lathe. The bed will have to be braced with diagonal strips, as shown in Fig. 31, and a board must be nailed across the legs at the rear for the treadle to be hinged upon.

The treadle (Fig. 30) will consist of two pieces of 1 by 2 inch wood 2 feet 6 inches long, connected at the forward end by means of a 6-inch board and fastened at the rear by means of two stout barn-door hinges. The treadle must be less than 3 feet wide so that the hangers can be fastened by means of heavy screws to it at each side.

But before the treadle can be fastened in place the crank shaft and pulley must be mounted in place. Holes are drilled in the cross-pieces D of the leg frames, to furnish bearings for the crank shaft. It is highly important that these holes be all in perfect alignment. In fact, it is better to bore the holes before the bed is put together. Take two of the leg frames and lay one on the other with the cross-pieces facing each other, then bore through both cross-pieces at the same time. One of these leg frames can now be used as a templet to bore the third frame. After the crankshaft and pulley have been mounted in the lathe, the pieces E are nailed on to serve as stops and keep the crankshaft from sliding endwise. The bearings of the crankshaft should be lubricated with graphite.

Fig. 32 shows how the headstock of the lathe should be constructed. For the spindle F use a ½-inch bolt 8 inches long and mount it in a couple of brackets G of the shape shown in Fig. 33. Mount the shaft about 5 inches above the bed of the lathe. Get a pulley about 3 inches in diameter with a set-screw to fasten it to the spindle and mount this in the bearings, setting them just far enough apart to clear the pulley. If the spring-board lathe has already been made it can be used to turn up this pulley out of a block of wood. The face of the pulley should be 1½ inches wide and the hub should project about an inch so as to provide room for the set-screw. The hub should be fully 2 inches in diameter. The face of the pulley should be crowned, that is, it should bulge a little toward the center line as shown. This will make the belt stay on.



FIGS. 29 TO 37.—Details of the speed lathe

After this much of the head has been finished, the lathe can be used to make itself. Connect the pulley to the flywheel with a belt of leather or canvas and work the treadle to revolve the pulley shaft. Hold a hacksaw against the body of the bolt, just back of the head, to cut the head off, then, with a file held against the spinning shaft, or spindle, taper each end off to a point. At the left of the head mount a thrust block H, as shown in Fig. 32. In this block, at the precise level of the spindle, there should be a screw with a shallow socket drilled into it just deep enough to receive the point of the spindle. It is the head end of the bolt that bears against the thrust block; the other, or threaded end, which must be furnished with a pair of nuts, is arranged to carry the face plate of the lathe.

The tailstock is made just like that of the spring-board lathe, except that it is furnished with a center that can be adjusted. Use a ⅜-inch bolt for the purpose, with a threaded end filed down to a point. Bore a shallow hole in the face of the tailstock slightly smaller than the nut and then drive the nut into it. The bolt can be adjusted to the work by threading it through the nut, after which it is firmly clamped by a nut, preferably a wing nut, on the other side of the tailstock (see Fig. 34). The lathe will have to be fitted with a couple of chucks, one a drill chuck for holding small drills, and the other a jaw chuck for holding pieces of work. The drill chuck will have to be bought from a hardware store of a size to fit on the spindle of your lathe, as this is too difficult a piece for a boy to make without having first-class machine tools to work with. The drill

chuck is a most important attachment for a lathe, as it enables one to drill holes in metal without the use of a drill press. It is also useful for holding small pieces of work that are to be turned up in the lathe.

The jaw chuck is too expensive a piece for the average boy to buy, and so we shall have to make a substitute with our own hands. This will call for some neat work with the chisel. Cut out a disk of hard wood 8 inches in diameter and 1 inch thick. Bore a hole in the center of the disk to fit the spindle of the lathe. From the hardware store get three stout angle braces 2½ inches long and 1 inch wide. In the face of the pulley cut three channels just wide enough to receive the angle braces and just as deep as the metal of the braces is thick, so that when a leg of the brace is set in the channel its upper face will lie flush with the face of the disk (see Fig. 35). These channels must be equally spaced on the face of the disk and must radiate from the center. In the bottom of each channel a slot must be cut through the disk. At each side of the channel strips of metal, either brass or steel, are fastened to the disk with flat-head screws so that they will overlie the leg of the angle brace resting in the channel. Strips of this kind can be bought at a hardware store, but it will be a simple matter to saw them out by hand and drill the holes in them for the screws. Slots K will have to be cut with a file in each angle brace, as shown in Fig. 35, to receive the strips. The projecting leg of the angle brace should be sawed off and the lower of the two screw holes should be enlarged to receive a

⅜-inch machine screw or say a No. 24 screw 1½ inches long. Buy six such screws each with a hexagonal nut to fit. Insert three of these in the projecting legs of the angle braces and pass the other three through the screw holes in the longer legs of the angle braces and the slots in the disk so as to secure the angle braces to the disks. The former screws should be filed to a pointed end.

Our jaw chuck may be fastened to the live spindle of the lathe by clamping it securely between the two nuts. The angle braces are the jaws of our chuck. They are slid in their channels up against the work and clamped fast by means of the machine screws. This done, a finer adjustment to bring the work exactly in the center is obtained by turning the hexagonal nuts on the screws that project from the jaws of the chuck. As the base leg of each angle brace has two screw holes in it, a wide range of adjustment is provided. If the work happens to be very large, the jaws may be turned to face in the other direction so that they extend beyond the edge of the disk. Of course the adjustment screws in the jaws would in that case have to be turned about so that their pointed ends turned inward.

There is but one thing further to be done to make our lathe complete and that is to make a tool rest. A simple one, such as that used in the spring-board lathe, will do for most purposes.

The Forge

There is one more piece of apparatus that will be found very useful, although not absolutely indispensable in our workshop, and that is a forge. With it a workman (or

workboy, shall we call you?) can weld metal and braze objects together. It can also be used for heating the soldering iron, should you wish to try some tinsmithing. The construction of a forge is very simple. There is nothing mysterious about it. It is merely an apparatus for burning coal or charcoal with a forced draft so that the fire will be hot enough to melt some of the metals that have a high melting point or make them plastic enough to be welded together or bent into shapes that would be impossible with the same metals in a cold state.

The first thing for us to do is to hunt around for a couple of old dishpans. Such a pan is quite apt to be found somewhere around the house or in a public ash dump. It does not matter if it has been rusted through so that it is no longer serviceable for kitchen use; it will do very nicely for our purposes. One pan is to be used for the concrete fireplace and the other for the hood to carry away the fumes of the burning fuel. The fire pan should be mounted on legs so that it will stand at a height of about 30 inches. The best thing for this purpose will be pieces of 1-inch pipe, each fitted with a foot plate, so as to give it a good bearing on the floor of the workshop. However, there are not many boys who can afford to get pipe and pipe fittings, and they will have to use wooden legs for the forge. This may seem rather ridiculous and even dangerous, until we realize that although the blacksmith's fire is a very hot one it is also a very small one, and very little heat will reach the legs of the forge.

While we can do without pipe for the legs of the forge, we must have at least one piece to supply air to the fire.

The fireplace is made by filling the pan with concrete to within 1½ inches or 2 inches of the top. In the center of the fireplace or hearth there must be an opening for the forced draft, which comes to it through a pipe leading to the bellows, while at the bottom of the "tuyere," as the opening is called, there is a trap-door which may be opened to clear the tuyere of coals or clinkers that may have fallen into it. For this purpose, it is important that the top of the tuyere be smaller than the bottom, so that he clinkers will be sure to drop through, once they get into the opening.

If pipe legs are to be used we shall proceed as follows: Get a 1-inch tee (a T-shaped pipe fitting) and a 1-inch nipple (a short piece of threaded pipe). The length of the nipple will depend upon the depth of the concrete in the hearth. A hole must be punched in the bottom of the dishpan large enough for the tee A to be pushed through, as shown in Fig. 38, and then the nipple B must be long enough to reach up to the surface of the concrete. The pipe to the bellows is screwed into the horizontal branch of the tee and is long enough to reach out through a hole in the rear of the pan. Only three legs will be needed for this forge, one at the front and two at the rear. They should be of 1-inch or ¾-inch pipe, 30 inches long, or just long enough to pass through holes punched in the dishpan and come up flush with the top of the concrete hearth. To hold the pan in place while the concrete is being cast, hooks of heavy wire are bent as shown at C in the Fig. 39, so that at one end the hook catches over the end of the pipe while at the other it forms a step for the pan to rest upon. A couple

of such hooks for each leg will be found ample to hold up the pan. The legs should be fastened down to the floor with screws, and the pan very carefully leveled with the hooks. The tuyere should be set in place with the air pipe leading out through the pan at the rear. Any holes that may have rusted through the pan may be covered with a piece of tin or even a stiff piece of cardboard to keep the concrete from pouring through while it is in a liquid state.

The pan is now ready to receive the cement mixture. This should consist of one part Portland cement to two parts of good clean sand. The cement and sand should be thoroughly mixed while in the dry state and then the mixture should be wet down with water until it is of the consistency of heavy cream. Pour this into the pan until it is filled flush with the top of the nipple B. Let the mixture stand for a day or two without disturbing it, so as to give the concrete plenty of time to harden. A screw plug should be used to close the bottom of the tee as shown in Fig. 38. The projecting end of the air pipe should be connected by an elbow with pipe D running down to the bellows.

If pipe fittings are not to be had, a wooden stand should be built to support the dishpan. The legs should be slanted outward at the base so as to provide a steady support for the forge, and they should be braced with diagonal strips which, however, should not reach down to the foot of the frame or they will interfere with the operation of the bellows (Fig. 40 shows the construction). On this stand the dishpan should be firmly nailed. For the tuyere, a block of wood E should be prepared about 6 inches long and

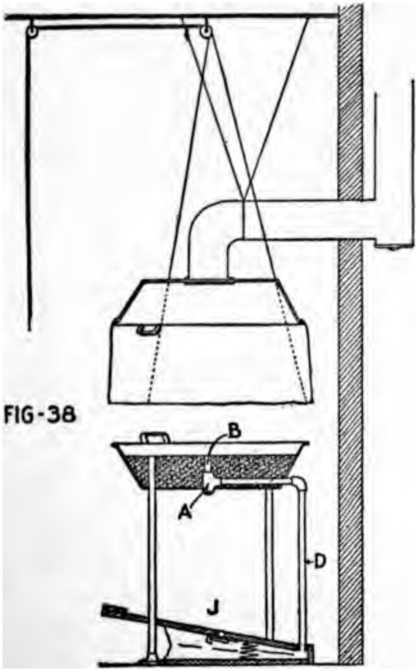


FIG-38

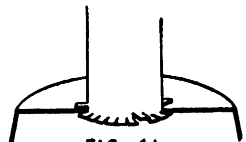


FIG-41

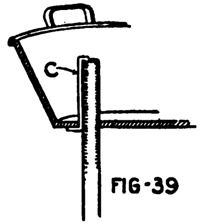


FIG-39

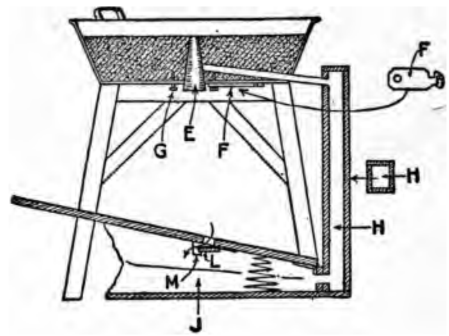


FIG-40

FIGS. 38 TO 41.—Construction of a simple forge

tapering from a diameter of 1 inch at one end to 2 at the other. This is the core for the hole that is to be cast in the concrete hearth. The door F for the bottom of the tuyere should consist of a piece of tin about 4 inches long and 3 inches wide. This should be swiveled to the bottom of the dishpan at one end and the other should be notched so as to engage a bolt head G when it is swung shut. The bolt for the swivel and the bolt for the latch may be secured in the pan by any makeshift arrangement, for instance by forcing them through a piece of wood or a bit of leather, which will hold them until they have been made fast by the hardening of the concrete in the dishpan. A piece of iron pipe for the air pipe should preferably be slanted upward as indicated in the drawing, with its end resting against the plug. The end of the pipe should be filed to fit smoothly against the plug, and it may be held in position by resting it on a tack driven lightly into the plug. The plug should be well greased to prevent any of the cement from soaking into it and gripping it fast. To keep the cement mixture from leaking into the pipe around the plug, all cracks should be closed with bees' wax or candle grease.

The pour is made exactly as described for the forge with iron pipe legs. The concrete must stand at least a day before the plug is driven out by hammering it from above. The air pipe leads into a wind box H made of wood in the shape of a long narrow box. Three-inch strips of wood are used and they are arranged as shown in the cross-sectional view of H, Fig. 40. This opens into the bellows J, which consists of a couple of boards 12 inches wide, which are hinged to an end board. A search of almost any public

ash dump will discover a coil spring such as used in upholstered chairs or in box springs for a bed. One of these springs between the boards will force them apart and hold the bellows normally open. In the upper board a hole about 2 inches in diameter is bored, and this is covered by a flap valve L on the under side, consisting of a piece of thin wood glued to a disk of leather. The leather bears against the valve opening while the wood serves merely as a stiffener. At one side the leather projects beyond the wood about ½ inch and is attached to the board by means of a couple of tacks, so as to serve as a hinge for the valve. The valve is prevented from dropping open too far by a nail M driven into the board just beyond the free end of the valve, with its head bent over so as to engage the end of the valve when the latter falls open. However, the valve should not drop much more than ¼ of an inch. The flexible sides of the bellows are made of canvas, glued and tacked to the boards. This canvas is soaked in linseed oil before being applied, so as to help it to retain the air. This, however, is not absolutely necessary. The canvas will make a pretty good bellows if applied without treatment. The bellows is about 2 feet long, but the upper board is longer than the lower one, forming an extension which serves as a pedal for the operator of the forge.

To carry away the fumes from the fire pit, a hood and chimney must be rigged up above the forge. Our second dishpan will be used for this purpose. Of course, if the forge is to be used out in the open, no such hood will be necessary, but it is really quite an advantage to use a forge

in a dark place, because then it will be easier to see the condition, that is, the redness, of the metal that is being heated. In such a dark place it is absolutely necessary that the fumes of the burning fuel be carried off. For this purpose we shall need a stove pipe. The size does not matter very much, but the larger sizes are sure to be more satisfactory than the smaller ones. With a can opener or by means of a cold chisel, a hole is cut in the bottom of the dishpan just large enough to fit over the stove pipe. With the tin shears the end of the stove pipe is snipped every inch or so, to a depth of an inch, forming a set of tabs. Three of these tabs are bent back so as to rest on the outside of the pan; then, after the pipe has been inserted in the hole in the pan, the rest of the tabs are bent back against the inner face of the pan so as to secure the smoke pipe to it, as shown in Fig. 41. The smoke pipe should lead into a chimney or it should pass out through the wall of the workshop and connect with a smoke stack that reaches well above the roof of the building so as to provide a good draft. The pan or hood will have to be supported by guy wires from the ceiling of the shop. It should lie not more than a foot or so above the hearth of the forge. The nearer it comes to the hearth, the more sure is it to trap fumes from the burning coals. However, there must be space enough under the hood to give free access to the fire. Some blacksmiths use a canvas curtain that hangs from the hood over the hearth when the fire is being started. Any boy can make such a curtain out of canvas, attaching the upper end of the curtain to a wire hoop such as come around barrels, and making the hoop just large enough to rest on the lip of the dishpan, to which it may be attached at

three or more points by stovepipe wire passed through holes punched through the pan. The bottom of the curtain may be weighted by sewing it fast to another hoop slightly larger in diameter. Cords fastened to three points on this hoop may pass over a pulley at the ceiling so that the curtain may be drawn up out of the way when it is not needed. To prevent the curtain from taking fire, it may be fireproofed by dipping it into a solution of sodium tungstate. However, this is not absolutely necessary, because the sparks that fly up from the forge will drop off the vertical canvas curtain, and there will be little chance of igniting it; at least such is the experience of the blacksmith who uses such curtains.

The fuel commonly used in a forge is soft coal which makes a black smoke, or coke or charcoal which are comparatively smokeless. Hard coal is also used to some extent, but it is not as satisfactory as the other fuels. There is no reason why a boy should not make his own charcoal. It can be done as follows: Dig a hole in the ground about 3 feet in diameter and a couple of feet deep. Shovel the dirt out to one side where it can be used to cover the pit again later. Gather a good pile of wood, at least 1 inch, and preferably 3 or 4 inches in diameter. Start a fire in the bottom of the pit and feed it until the pit is full of glowing embers and heaped up nearly a foot above ground. Then shovel back the dirt over the heap of burning fuel, covering it completely. Let the pit stand for a full day to cool, and then on removing the covering of earth you will find a mass of good charcoal which can be used to advantage in the forge.

Having built your forge, you must provide yourself with some sort of an anvil. It is hard to get a substitute for a regu-

lar blacksmith's anvil and every effort should be made to get such an anvil. If it is not to be found, a piece of railroad iron 8 or 10 inches long will make a poor substitute. It may be fastened to its support with regular rail spikes. Whatever the form of the anvil, it should be supported very firmly and solidly. The best form of support, no doubt, is a stump of a log sawed off with square ends so that it will stand solidly. On the upper end of this stump the anvil is secured by means of heavy nails or spikes. As for the use of the forge, it will be unnecessary to take up space here with instructions, when, by dropping into any blacksmith's shop, you can learn more in an hour than you could by reading a whole book on the subject.

CHAPTER III

WHAT A BOY SHOULD KNOW OF THE STARS

THE GREAT DIPPER. HOW TO FIND THE POLE STAR. CASSIOPEIA AS A STAR FINDER. HOW TO FIND THE TRUE MERIDIAN. HOW A TELESCOPE ENLARGES AN OBJECT. CONSTRUCTION OF A 2¾-INCH TELESCOPE. A MOUNTING FOR THE TELESCOPE. ADJUSTING THE MOUNTING. SETTING UP THE TELESCOPE. SOME USES FOR THE TELESCOPE.

It may seem like a big jump from the cellar workshop to the realm of the stars, but there is a very good reason why we should take up the subject of astronomy right at this point. Until recently the man who busied himself with tools had very little use for the stars. He left that to poets and dreamers. As for any practical value in astronomy, he saw none unless it was to pilot ships across the sea. But of late a great many people have been turning their gaze to the heavens not only because of the wonders that are to be found there, but because in many cases their lives have depended upon their ability to read the stars.

It was during the Boer War that the British soldiers first awakened to the necessity of knowing the stars. Much fighting was done at night, and the Boers, accustomed to living out on the plains, could find their way about readily by means of the "lamp posts" of the heavens, thus putting the British to a great disadvantage. And so a soldiers' book of astronomy was prepared and was just about to be intro-

duced into the British army when the great European War broke out.

Now the need of knowing the stars has made itself felt among all the fighting armies; for the man who knows the constellations can get along without the use of the compass. In fact, no other light is permissible on the battle-field, or along the trench line, and detachments of soldiers are guided to their destination by ordering them to move so many miles in the direction of a certain well-known group of stars. Since warfare has moved up into the skies, the use of stars for aeroplane and dirigible navigation has become indispensable.

Every soldier should know the stars, and so should every hunter, every camper, and every engineer. Particularly is this true of the engineer, not only because he has to do a lot of exploring and must know how to make his way abcut even when his compass goes wrong, but it is his job to make accurate measurements on the earth and these he can not make without some fixed starting point or some fixed direction. There is nothing on earth that is absolutely fixed which can be used as a guide or monument for the surveyor and so the only guide is to be found in the heavens. Every surveyor has to know the stars at least well enough to correct his compass, for a compass does not always point true. If you bring a piece of iron near a compass the needle will be deflected. On board ship there are sure to be large masses of steel and iron about that will pull the compass needle out of the direction in which it should be pointing, and the only way to correct the compass is to place balls of steel or iron in such a position that they will offset and correct

the distortion. The same is true of the earth. There are deposits of iron that bend the magnetic lines of the earth and make the compass needle point to the east or the west of north. Besides this difficulty there are other deflections of the compass needle from year to year and then there are apt to be magnetic storms occasionally that will throw a compass needle off altogether. Altogether the compass is a very unreliable instrument, and so it is very important for a civil engineer to know his stars at least well enough to be able to set his compass by them.

It is because surveying is the first step in civil engineering and because a good all around surveyor should know the elements of astronomy that we are going to take this sudden leap out of the cellar workshop into the realm of the stars. Then, too, if you are going to do any surveying you will have to know something about the construction of a telescope, because miniature telescopes are used in surveyors' instruments, and while you are about it you may as well build a large one and use it for studying the stars.

Before you start to build a telescope, you had better learn to know the stars. When you begin to study them you will find that they are not mere sign posts. Each has its own particular interest and tells a wonderful story in the light that it sends us through trillions and quadrillions of miles of space. It is rather difficult to learn to know the stars without the help of some one to point them out, but with a good star map, a little patience and the hints that are given below, any bright boy should be able to learn a few of the most important constellations or groups of stars. The beauty of it is that each constellation you learn to recog-

nize will help you to locate others, and after you once get started the rest will be easy.

We are not going to publish maps of the heavens in this book, because we haven't room for them, but they can be bought for a moderate sum and many of the newspapers and periodicals publish monthly maps of the part of the heavens that is conveniently situated for observation at the time.

Any boy who has watched the stars knows that they travel around us in great orbits just as the sun does. Of course they don't go around us at all, but it seems as if they did, when, really, it is the earth that is turning around on its axis. Now the earth goes around the sun, but it does not go around the stars, and so apparently the stars seem to travel faster than the sun, taking about four minutes less than twenty-four hours to complete an apparent revolution. In other words, they rise four minutes earlier each night, and so at the end of a year they gain an entire day over the sun.

The Great Dipper

Nearly every one knows the Great Dipper—seven stars that take the form of a dipper with a bent handle. It is a group of stars that can be seen at any time from practically all of the United States, because it is so near the North Pole of the heavens that it does not dip below the horizon as it sweeps through its daily orbit around the pole. Very close to the pole of the heavens is a star called Polaris. Fig. 42 shows the Great Dipper in four positions around this Pole star. Of course it makes a complete circuit of its orbit

every day, but, as we said above, it takes four minutes less than a full day to do it in, and so its early evening position in the autumn will be low in the northwestern sky, in winter it will be to the east of the Pole star, in the spring above it,

Fig. 42.—Position of the Great Dipper at about 8.30 p. m. during the four seasons

and in midsummer almost overhead. It will seem strange at first to find West at the right side of the map and East at the left, but you must remember that you look up at the stars, and so the map must be held over your head in order to get the map into proper relation with the points of the compass. If you face north and hold the map over your

head with North of the map pointing north, East will come to the right and West to the left, just as in a geographical map.

How to Find the Pole Star

In astronomical maps the stars of a constellation are usually identified by means of Greek letters. In the lower part of Fig. 42 will be found the Greek letter names of the

Fig. 43.—Using a foot rule to measure angular distances between stars

stars of the Great Dipper. Two of the stars of the Dipper are known as the " Pointers " because they always point to the Pole Star, no matter what position the Dipper occupies or how it is turned. If we draw an imaginary line from the start Beta to the star Alpha and extend it for a distance about equal to that between Alpha and Eta, we shall

come to a bluish star, which is Polaris, or the Pole star. It is not a very bright star, but it is the most important one in the northern hemisphere.

It is a good plan to use a yardstick or foot rule to measure distances roughly. Hold the stick before you at arm's length with one end of it in line with the Pole star and note where the star Alpha seems to touch it. (See Fig. 43). This will represent 28 degrees, or say roughly 30 degrees. Now divide this length into six parts so that each will represent about five degrees. The distance between Alpha and Beta is 5 degrees. Of course this will be a very rough scale, but it will help in locating some of the stars. It is well, too, to have a little electric flash lamp along when trying to find the stars with a map, so that the map may be studied and the scale on the yardstick read in the dark.

Cassiopeia as a Star Finder

On the opposite side of the Pole from the Great Dipper there is another very important constellation which also never sets in the latitude of the United States. It makes a very useful sign post as well as an excellent guide for identifying other constellations. If we draw an imaginary line from the star Epsilon of the Dipper, through the Pole star, and extend it about 30 degrees beyond, we shall come to the middle of a group of stars that look like a very sprawling ragged W (see Fig. 44). This is the constellation of Cassiopeia. Those of you who have read the Greek myths will recognize the name. Cassiopeia lies in the Milky Way—a filmy, cloud-like band which stretches clear across the sky

and which under the telescopes is seen to be made up of myriads of little stars.

In the Fall when the Great Dipper lies low in the evening sky, Cassiopeia is well over head and can be used as a guide

FIG. 44.—Relation of Cassiopeia to Polaris and the Great Dipper

for the location of many other constellations. Draw a line from Delta of Cassiopeia, through Gamma,.and extend it for about 40 degrees and you will come to a bright, first magnitude star known to the Arabs as "Deneb," but now-a-days usually referred to as Alpha of the constellation of the Swan

(Fig. 45) The other stars of this group are not so very conspicuous, but with Alpha at the head they take roughly the shape of a cross and sometimes are known as the Northern Cross. As soon as you have found a constellation and learned to recognize it, note its relation to Polaris so that you will be able to tell where Polaris is, no matter whether it is in sight or not. Suppose that the sky were overcast and that you could not see much of the heavens except here and

FIG. 45.—Cassiopeia as a guide to near-by constellations

there through a rift in the clouds, and suppose that through one of those rifts you made out the constellation of the Swan, if you knew your stars you could draw a mental line from Beta and Delta of the Swan and extend it for about 45 degrees giving you roughly the position of the Pole star and the direction of true north. If Cassiopeia were the only constellation visible you would have no such guide stars, but you would know in about what direction the Pole star lies and that a line connecting Delta and Gamma of Cassiopeia lies about at right angles to the line that runs to the Pole star.

If we start a line at Gamma of Cassiopeia, extending a line through Delta westward, we shall come to the constellation of Perseus. This is a very interesting group because it contains a curious winking star, Beta. The Arabs called this star " Algol " or the " Demon," because of its mysterious

FIG. 46.—The triangle of first magnitude stars

behavior. Every three days (2 days, 20 hours and 49 minutes, to be exact) this star suddenly loses about five-sixths of its light, and remains dim for eighteen minutes. Then its light comes back and it is as bright as ever. The explanation of this strange phenomenon is that there is a dark companion or a dead star revolving about Algol which bobs its head in the way of Algol's light, partly eclipsing it every so often.

The Swan is rather easily picked out because it contains a first magnitude star. There are several other constellations with first magnitude stars that can be found with the aid of Cassiopeia and the Swan. A line from Alpha of Cassiopeia, extended through Beta, past the Swan, and for a distance of about 60 degrees will bring you to one of the brightest stars in the Northern skies, the star "Vega" or Alpha of the constellation Lyre. This is accompanied by a group of faint stars that take the shape of a very sprawling W. In the Milky Way, about 35 degrees from Vega and slightly farther from Deneb, is another first magnitude star known as "Altair," in the constellation Eagle. These three stars, Deneb, Vega and Altair, make a pretty triangle that is well placed for observation in the early evening hours of August, September and October (see Fig. 46). In the middle of September, for instance, the triangle is almost directly over head at 8 o'clock in the evening. Later in the season, say in December, we can pick out some other constellations that possess a first magnitude star.

To the east of Cassiopeia along the Milky Way and about 40 degrees away, is the brilliant start "Capella" of the constellation Auriga (Fig. 47). This is easily identified by the little triangle of third magnitude stars close to it. This is a very important star to become acquainted with, because its orbit is so near the pole that it dips but slightly below the horizon, which means that it is visible practically all the time to boys who view it from the latitude of New York, while to boys who live farther north, say above the latitude 45 degrees North, it does not set at all, but seems to circle around the Pole star just as the Dipper does. It

is the nearest first magnitude star to the pole, the next nearest being Vega on the opposite side of the Pole star. Vega makes a larger circuit of the heavens and you have to observe it from a latitude of 52 degrees North in order to see it make a complete circuit without dipping below the horizon. To boys in England, for instance, Vega never sets or rises.

FIG. 47.—Relation of Auriga and Perseus to Cassiopeia

A boy who has succeeded in identifying all the constellations so far mentioned will have no difficulty in locating all the other principal ones, with the aid of a good map. Roughly along the line of the Milky Way he will find very interesting the Twins with the two first magnitude stars Castor and Pollux, the Bull with its red eye Aldebaran, and the little group of seven stars called the Pleiades. By the way, it takes a good pair of eyes to see more than six stars in this group. Some people call this the Little Dipper,

which is incorrect. The Little Dipper is up north—a group of rather faint stars, shaped like a dipper with a curved handle that ends in the Pole star.

Beyond the Bull is the brilliant constellation of Orion, with its belt of three brilliant stars that point roughly toward the very brightest star in the heavens, known as Sirius, in the constellation known as the Great Dog. The Little Dog is across the Milky Way from the Orion. It has only one very prominent star called Procyon, which may be found by extending a line from Gamma of Orion through Alpha of the same constellation.

The Great Dipper as a Star Finder

If a boy starts to study the skies in the spring and early summer, when Cassiopeia is not favorably situated for an index of the heavens, he can make use of the Great Dipper as shown in Fig. 48. A line drawn from Alpha through Delta and extended about 45 degrees will bring us to the star " Arcturus " in the constellation of the Herdsman, while a line from Alpha through Gamma will bring us eventually to another first magnitude star called " Spica," which is in the constellation of the Virgin. A third line drawn from Alpha through Beta will bring us to the constellation of the Lion with its first magnitude star Regulus. North of Regulus is a group of stars that curve around in the shape of a sickle with the star Regulus in the handle. In fact, this group of stars is often called the " Sickle."

Of course, in addition to the fixed stars, there are other objects in the sky that wander around among the constellations; that is, they seem to wander among them, but, as

a matter of fact, they are very near us and almost as far from the stars as we are. They are the planets that circle around the sun just as we do. Many of them are far brighter than the stars, and unless the amateur astronomer keeps track of the planets and knows where they are to be

FIG. 48.—The Great Dipper as a star finder

found, from month to month, by consulting an almanac, they are likely to bother him in identifying the constellations.

HOW TO FIND THE TRUE MERIDIAN

Now that we know something about the constellations, we can take an observation that will show us the exact direction of North, or, as an astronomer would put it, the true meridian. The meridian of any place is the true north and south line traced on the vault of the heavens directly over that place. You will not need any elaborate instru-

ments; just a watch, a plumb line, a pail of water, and a piece of tin or cardboard with a narrow slit cut in it. It is a rough and ready equipment such as any one could rig up out in the wilderness to determine the correctness of his compass. The method of taking the observation is not a new one; it was used a hundred and fifty years ago to determine the state line between Pennsylvania and Ohio.

We have spoken of Polaris as the Pole star, about which the other stars of the northern skies revolve. If we pointed a camera at Polaris and made an all-night exposure we should find trails of light on the photograph, showing the paths of the stars through the heavens, and these star trails would all circle around Polaris, not complete circles, of course, because your night is only, say, 12 hours long, and it takes 24 hours for a star to make a full circle around the celestial pole. But Polaris itself would show a trail of light because it is not exactly on the North Pole of the heavens, but 1¼ degrees away from that spot. Now twice every twenty-four hours Polaris must cross the meridian, once above and once below the pole. It happens that at about the same time the star Delta of Cassiopeia is directly above or below Polaris, while Zeta of the Great Dipper is also in line with the two stars, but on the opposite side of the pole. Hang a plumb line from the eaves of a house or a branch of a tree and sight on these stars with one eye closed, keeping Polaris covered by the string. At the moment that Delta of Cassiopeia or Zeta of the Great Dipper is also covered by the string, you will be facing almost due north. To get it with greater accuracy, you will have to follow the plan pictured in Fig. 49. The observation can best be made in October

when Delta of Cassiopeia will be found below Polaris during ing the early evening hours.

Pick out a spot where you have a clear view of the northern sky and hang up a plumb line about 10 or 12 feet

FIG. 49.—How to find the true meridian

long. To keep the plumb line from swaying, let the plumb bob dip in a pail of water. Be sure that the plumb bob does not touch the bottom of the pail. A few feet south of the plumb line set up some sort of a support, such as a barrel or a box, and be sure to have the top level. Make a peep sight out of a piece of tin or cardboard with a narrow

slit in it and tack this fast to a block of wood, being careful to have the slit vertical (see Fig. 50). Now sight through the peep sight, adjusting the block to the right or the left so as to keep the plumb line directly in the middle of the slit and at the same time covering Polaris. At the instant that the plumb line crosses Delta of Cassiopeia, look at your watch and then keep the plumb line on Delta instead of Polaris. At the end of 3 minutes and 42 seconds Delta will have cut the meridian, and your observation will be ended

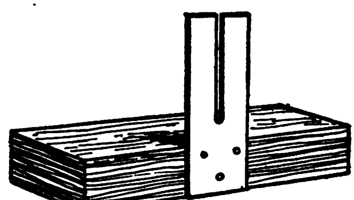


FIG. 50.—The peep sight

for the night. You can leave the peep sight on the barrel head undisturbed, and the next morning you can drive a couple of stakes in the ground, sighting through the peep sight and upon the plumb line to get them into perfect alignment with the meridian. Having a true north and south line between these stakes you can compare your compass with it and see how nearly correct it is.

How a Telescope Enlarges an Object

After you have learned enough about the stars to enable you to pick out the constellations you will not be satisfied until you have a telescope with which you can study some of the wonders of the heavens. There is nothing very

mysterious about a telescope, and it is not very difficult to make one with which you can have a lot of fun.

To understand the principle of the telescope, take an ordinary reading glass and hold it up in front of a piece of paper. If you do this before a window in a fairly dark room you will find, on the paper, after moving the glass back and forth until you get the right focus, an image or picture of the scenery outside the window. This will be upside down and of course it will be a miniature of what you see out of the window with your own eyes. Now all you need is a

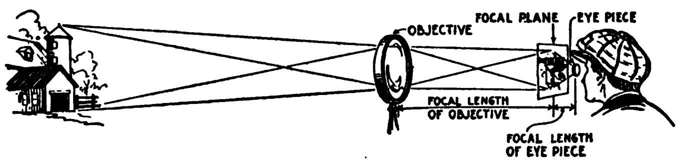


FIG. 51.—How the telescope works

microscope or pocket magnifying glass to enlarge the image on the paper. If the paper is very thin the image will show right through it. Then, if you let a friend hold the reading glass and the paper, you can use the pocket magnifying glass back of the paper to magnify the image (Fig. 51). But the paper is not at all necessary except to show you just where the image is. If your friend pulls away the paper while you are looking through the pocket lens at it, you will get a very clear telescopic image.

That is all your telescope is—one glass, called the "objective," that casts an image, and another called the "eye-piece," with which the image is magnified. The longer the focus of the objective and the shorter the focus of the eye-piece, the more powerful is the telescope. The place where

a piece of paper would catch a sharp image is known as the focal plane.

The power of the telescope is found by dividing the focal length of the objective by the focal length of the eye-piece (the focal length is the distance from the lens to the focal plane). For instance, if the focal length of the objective is 12 inches and the focal length of the eye-piece 1½ inches, the telescope will have a power of eight diameters, that is, it will make things look eight times as large as they appear to the naked eye.

In a telescope two tubes are used, one of which telescopes within the other. One of these carries the objective and the other the eye-piece, and by sliding one tube within the other, the two lenses can be brought to the proper focus. Of course the image is upside down, but that does not matter when looking at the stars. If the telescope is to be used in daylight for use at sea or on land another glass will have to be added to the eye-piece to turn the image right side up again.

While a reading glass will give us a fair objective for a small telescope, it has its drawbacks. The images are apt to be fringed with all the colors of the rainbow, and the only way to cut this down is to use diaphragms, like the stops of a camera, so as to cut off the light from the edges of the lens.

Construction of a 2¾-Inch Telescope

At best a reading glass makes a poor objective for a telescope. It has too short a focus and is usually too large in diameter for so short a focus. There is a lens on the

market, however, that can be procured for about three dollars which makes a fair telescope objective, and that is an auxiliary portrait lens known as the "Ideal," which is used on a camera so as to fit it for taking portraits and close-up views of objects. Get a No. 12 size, which is 2¾ inches in diameter. It will be found to have a focus of about 40 inches. It is really made up of two lenses cemented together with Canada balsam which is a transparent cement. It will make a much better objective for a telescope if the two lenses are separated and spaced apart about ⅛ of an inch. They are usually held in place in a brass cell by means of a retaining ring, which may be pried out, releasing the glasses from the mounting. Then the lenses may be separated by soaking them in warm water. After they have come apart, their cemented faces should be carefully wiped off with alcohol and polished clean with a soft rag. Great care should be taken not to scratch the surface of the glass during this operation. The lenses may now be set back in their cell, but this time with a ring of cardboard ⅛ of an inch thick between them.

The telescope tube may be made of paper by winding strips of paper spirally around a wooden form and gluing them with shellac while winding, but this is not a very simple thing to do, and had better not be attempted. Mailing tubes may be used, but it is hard to find one of exactly the right size and expensive to have them made to order. A number of short mailing tubes may be fastened together to make a tube of the proper length by attaching them with screws to a pair of wooden rods. The rods should be on the

inside of the telescope tube and they may be backed with a block of wood wedged between them while the screws are being screwed home. The inside of the tube will have to be painted black. The rods can be painted before assembling the tube, and the tube sections can also be painted before they are put together. The tube can be finished off by gluing on an outer layer of black cloth.

Of course it is not necessary to have a round tube. A square tube will do just as well. We can take three pieces

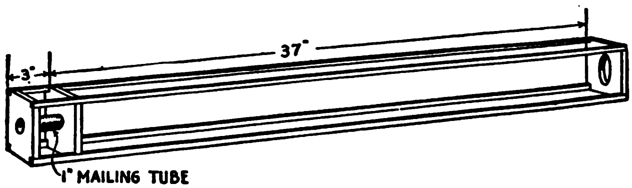


FIG. 52.—The construction of a square telescope tube

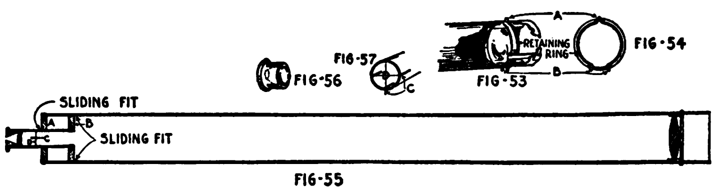
of board, each 4 inches square and with a hole in one just big enough to receive the cell of the objective and a hole in the other two just large enough to receive a 1-inch mailing tube. Then these can be connected by four rods, one at each corner, the two squares for the eye-piece end being spaced 3 inches apart. The piece of mailing tube is glued in place as shown in Fig. 52. After this skeleton has been painted a dull black the sides can be closed by strips of cardboard, also painted a dull black, and nailed or glued to the corner rods. This done, the telescope can be covered with black cloth to give it a neat appearance. The tube for the eye-piece mounting will have to be just large enough to slide snugly within the 1-inch mailing tube. This will

make a perfectly good telescope body, and one that can be constructed very easily and cheaply, but there are some who will not be satisfied with anything that does not look like the ordinary telescope.

If a cylindrical body is insisted upon, probably the best thing to use is a tin tube which can be made up by any tinner for a small sum. A tube such as is used for a leader on a house will make a good telescope body. The tube should be a trifle larger in diameter than the cell of the objective and a couple of inches longer than the focal length of the objective, say 42 inches. In order to protect the lens, it should be set at least 2 inches inside the end of the tube. Out of a piece of tin three hooks should be made to the form shown in Fig 53 so that they will catch the inner edge of the cell of the objective and hook over the edge of the telescope tube. These hooks will have to be very carefully made so that they are all just alike, or the objective will not lie at right angles with the axis of the tube. The tube should be just large enough to receive the cell of the objective with the hooks on it. To make sure that the cell does not drop out, a retaining ring must be used, such as is found on bicycle lamps, to hold the lens in the lamp. This ring is made out of spring brass or steel wire, of the shape shown in Fig. 54. A couple of slots are cut in the telescope tube just in front of the point where the objective cell is to come, and after the lens is in place the retaining ring is sprung into place with the point A in one slot and the ends B in the other. If the cell is smaller than the tube it should be fitted into a piece of cardboard tube which may be wrapped

with paper until it fits. Of course the paper will have to be glued on while it is being wrapped around the pasteboard tube.

For the opposite end of the tube cut out two disks of wood each with a hole in the middle just large enough to receive a 1-inch mailing tube. These disks must be exactly alike except that one should be a shade larger, for it is to fit tightly in the end of the tube, while the other is to be fastened to the end of the eye-piece and is to slide snugly but smoothly in the tube. The best plan is to fasten two pieces



FIGS. 53 TO 57.—The construction of the telescope

of board together with a couple of brads or small nails and bore the holes in them and turn them up on the lathe as if they were one piece. Then the two disks can be separated and one of them can be made slightly smaller by the use of sandpaper or a file.

For the eye-piece lens, get a small magnifying glass of 1-inch focus and about ¾ inch in diameter. Take a spool with a body just large enough to fit snugly in the mailing tube. Cut off about ¾ of an inch of the spool and ream out or taper the hole in the spool, as indicated in Fig. 55. Take three narrow strips of tin and fasten them to the body of the spool with the smaller-sized tacks (Fig. 56). Each strip

should be bent over at the end so that it catches the lens of the eye-piece and holds it in place when the spool is inserted in the mailing tube, but when the spool is drawn out the tin fingers can be spread apart and the lens taken out to clean it. The mailing tube should be about 4 inches long. First the larger, A, of our two disks is slipped upon the tube and then the smaller one, B, is fitted on and glued fast. A couple of tacks pressed through the tube into the wood will help to hold the disk fast in case the glue is not strong enough or is improperly applied. Then the eye-piece is fitted into the main telescope tube and the larger disk is made fast to the tube by means of tacks. The eye-piece can then be adjusted in or out to the proper focus while the inner disk, B, supports the inner end of the mailing tube and keeps the eye-piece in perfect alignment with the objective.

The tin body of the telescope can be covered with black cloth so as to make it look a little more neat and trim. But far more important is it to paint the inside a dull black, so as to do away with confusing reflections.

It will be a distinct advantage to have the center of the telescope field marked by a pair of cross-hairs. These hairs must be put in right at the focus of the eye-piece so that they will be visible when looking through the telescope. Cut four fine slits, C, Fig. 57, in the eye-piece tube at about the focal plane of the eye-piece and with a fine needle run a black silk thread D across from one slit to the opposite one, and through the other two slits run a second thread at right angles to the first one. Now, looking through the telescope at the blue sky or at some blank white surface, shift the

threads back and forth in the slits until they are in sharp focus. A drop of glue will hold each thread in place, after which the slits may be covered with a band of paper.

A Mounting for the Telescope

Having built our telescope, the next job is to make a suitable mounting for it, but before we proceed with the mounting we must know something about the way that astronomers locate the stars. This may seem complicated because there are new words to learn, but if you have a little patience you will find the whole subject very simple after all.

An astronomer finds his way about the heavens just as a mariner does on the sea. The earth is laid off in imaginary lines of latitude and longitude, as every boy who has studied geography knows. The lines of latitude run parallel to the equator, while the lines of longitude run from pole to pole, cutting the parallels of latitude at right angles. Now the astronomer imagines the same kind of lines in the sky. To us on the earth the sky looks like a great hollow sphere, with the earth at the middle of it, and on the inside of this sphere the astronomer traces his imaginary lines of longitude and latitude.

We have already learned that there is a spot in the sky known as the *celestial pole*. It is the spot that lies directly over the north pole of the earth. There is another spot over the south pole of the earth that marks the south pole of the heavens. In the same way there is a great circle over the equator of the earth which is known as the *celestial equator*. Parallel to the celestial equator there are imaginary lines

that correspond to the parallels of latitude on the earth, but astronomers call them *declination circles,* while running from pole to pole are lines that correspond to the lines of longitude on the earth, and they are known to astronomers as *hour circles.* In geography there is one line of longitude, usually the one that passes over Greenwich, England, that is used as a starting point and the other lines are counted east and west of Greenwich. In astronomy there is one hour circle that is used as the starting line. It passes almost through the star Beta of Cassiopeia. From this the others are counted not east and west but eastward only, and the distance eastward is known as the *right ascension.* Instead of counting the hour circles in degrees as are the longitude circles of the earth, they are counted in hours and minutes, and there are twenty-four hour circles in the sky.

If a mariner reported that he had seen a wreck at Lat. 32° S. Long. 43° W., you could get out a chart and measure down 32 degrees south of the equator, and then you would run along this parallel until you came to the longitude 43 degrees west of Greenwich and you would know exactly where the wreck was located. In the same way an astronomer may say a star is located at R. A. 6 h. 30 m., Dec. + 20°54′. You can find this spot on the chart of the heavens by running along the equator until you come to a point just half way between the 6 and 7 hour circles. From there you measure 20 degrees and 54 minutes north of the equator and you have the location of the star. You measure north because there is a plus sign in the declination. If a minus sign were used, you would measure to the south.

Now the proper way to mount a telescope is with two axes, so that when it turns on one axis it can be moved around to the different hour circles, while on the other axis it can be swung to any declination desired. One of these axes must point toward the celestial pole and is called the polar axis, while the other is at right angles to the first and is called the declination axis. On each axis there is a dial, one marked off in degrees of declination and the other in hours and minutes of right ascension, so that if the location of a star is given, it is a simple matter to set the mounting accordingly, and the star will appear in the field of the telescope. Such a mounting is known as an *equatorial mounting.*

First of all we shall need a very substantial tripod. For the head (A, Fig. 58) of our tripod, let us take a disk of wood 8 inches in diameter and an inch thick. If desired, a square tripod head may be used, in which case an 8-inch circle should be inscribed upon the board and this should be divided into three equal parts to indicate where the legs are to be attached. At these points bearing blocks B are fastened to the tripod head between which the legs are fitted (Fig. 58).

The legs C are made out of six 1 by 2 inch strips of wood 4 feet 6 inches long. Two strips are used for each leg. They are nailed firmly together at the lower end for a length of about 2 feet while the upper ends are spread apart by means of a space-block, as shown in Fig. 59. The legs are sprung into place between the bearing blocks of the tripod head and are held in place by screws which pass through

the blocks and enter holes in the leg strips. The leg strips are rounded off at the upper end and they are tapered off at the lower end so as to come nearly to a point. However, before the two leg strips are nailed together, an eight-penny nail is fitted between them with its pointed end projecting about ½ inch. The nail is crushed into the wood by hammering the two strips together, and then it is firmly held when the two strips are nailed together (as shown in Fig. 59).

On the head of the tripod is mounted a board, D, Fig. 60, measuring 6 inches square and 1 inch thick, to which is hinged another square board, E, of the same dimensions. A couple of substantial hinges will have to be used so as to make a firm connection between the two. The board D is made fast to the head of the tripod by means of a bolt and thumb-nut, as shown in the sectional view, Fig. 61. A hole is bored through the center of piece D and head A, just large enough to receive the body of the bolt, and with a chisel a socket is cut in the upper face of the board D for the head of the bolt. This should be a driving fit so that the nut will not be liable to drop out and be lost when the mounting is taken off the tripod.

Mounted on the upper edge of the piece E is the hour circle of the mounting. This consists of a disk of thin wood, cardboard, or tin, which must be just 7 3/16 inches in diameter. While we are at it, we may as well cut out two such disks, one for the hour circle on the polar axis and the other for the declination circle on the declination axis. The first circle is to be divided into hours and minutes and the other into degrees and minutes. The hour circle will

have to be divided off into 24 hours and if our circle is just 7 $^{8}/_{16}$ inches in diameter, it will be very close to 360/16 in circumference. So we can lay off the circle in 24 equal parts spaced $^{15}/_{16}$ of an inch apart for the twenty-four hours. The hours should be marked with the Roman numerals, thus: O, I, II, III, IV, etc., to XXIII. Then between the hour marks we may lay off the space in sixteenths of an inch and, as there will be fifteen of them to the hour, each one will represent an interval of four minutes. The hours will have to read clockwise from left to right in the same direction as they do on a clock face.

The other circle may be laid off in sixteenths of an inch, each of which represents a degree, with a heavy line for every tenth degree. Starting in both directions from zero, mark the heavy lines 10, 20, 30, etc., up to 90, and then 80, 70, 60, etc., until you come to zero again. At one of the 90 marks print the word *North* and at the other the word *South*.

The hour circle is to be mounted on the polar axis at the edge of piece, E, of the mounting, with its calibrated face inward. A hole is bored into the edge of the piece E to receive the polar axis, H, which in this case is a bolt ⅜ of an inch in diameter and 4 inches long. This hole is intercepted by another, bored in the face of the board E, as shown at F, Figs. 60 and 62. In this hole a nut G is introduced into which the bolt H is screwed while another nut, I, bears against the edge of board E holding the bolt fast. The board E must be tipped so that the polar axis will point to the north pole of the heavens. The angle will always be the

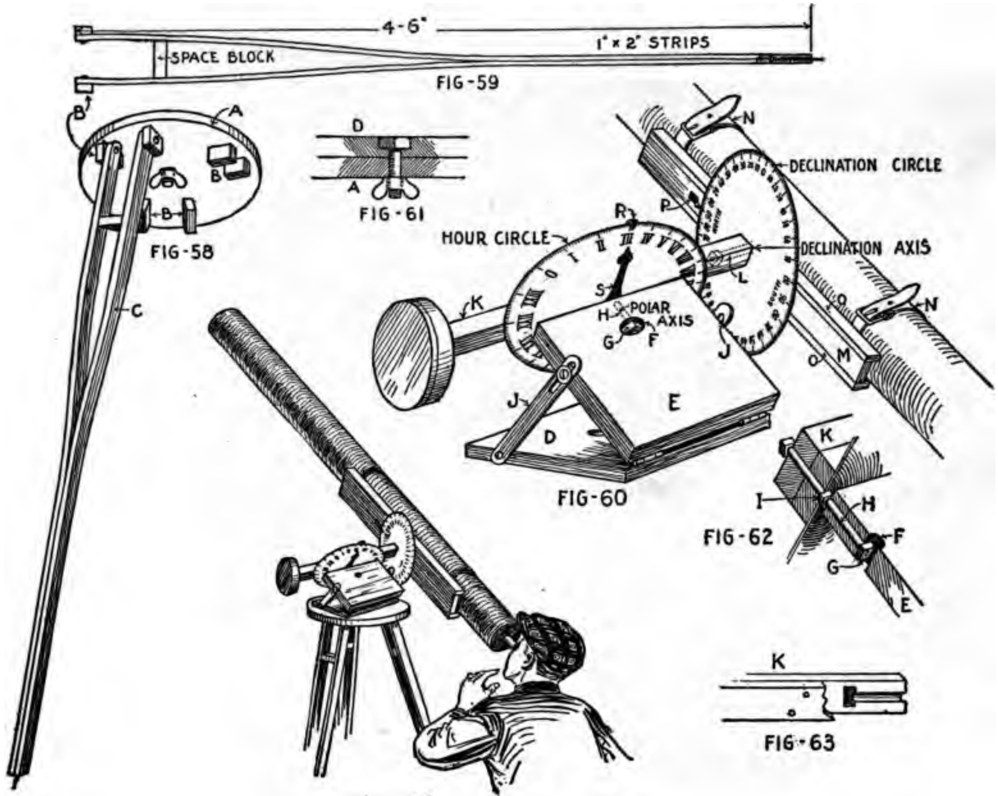


FIG-64

FIGS. 58 TO 64.—An equatorial mounting for the telescope

same at the latitude of the place where the telescope is used. For instance, boys in Philadelphia, which is in latitude 40 degrees north, will have to tip the board E up until it makes an angle of 40 degrees with the board D. It will be rather difficult to get this exact, and so we shall have to allow for a certain amount of adjustment after the mounting is completed, when we can use the telescope and the stars themselves to correct our mounting. Set the board as nearly as possible to the angle desired, and then fasten it in place with a pair of straps J, which may be of brass, although they could be made of hard wood. They are attached to the boards with round-headed screws. At the upper end of each strap the screw hole is extended into a slot so as to provide for the necessary adjustment. A washer should be slipped under the head of the screw so as to keep it from sinking into the slot.

The declination axis of the mounting consists of a stick of wood, K, measuring 2 inches square. It will be a distinct advantage to build this up of two sticks each measuring 1 by 2 inches in cross section. The stick should be 15 inches long, and projecting from one end there must be a 3/8-inch bolt, L. The two sticks should be firmly clamped in a vise and then a hole should be drilled in the end of the stick a trifle smaller in diameter than the bolt. The hole should be about 2 inches deep. After it is bored, the sticks may be separated and the hole enlarged at the inner end so as to receive the head of the bolt, as illustrated in Fig. 63, in which one of the sticks is broken away to show the half socket for the bolt in the other stick. The bolt should be

about 4 inches long, but it does not need to be threaded throughout, as in the case of the polar axis. After the sticks have been put together again and firmly fastened with screws, the declination circle is made fast to the end of the axis, a hole being cut in it for the bolt to pass through.

A holder, M, is now mounted on the projecting bolt. This should be 2 inches wide, ½ inch thick, and 2 feet long. The bolt hole in the holder M must be counter sunk, so that the nuts on the end of the bolt will not project above the face of the holder. In countersinking a hole, be sure to bore the larger hole first so that there will be something for the worm on the end of the bit to bite into. Two thin nuts should be used, one to secure the holder so that it will not turn too freely, and the other to lock the first nut in place and keep it from working lose. The telescope is to be fastened to the holder with straps, N, and consequently the outer face of the holder should be hollowed out to fit the round of the body of the telescope, but as this is rather hard to do, a lip may be formed at the top and bottom of the holder by nailing strips, O, to it (see Figs. 60 and 64).

A pointer, P, must be fastened to the holder M. This should be a piece of wire or a bit of tin with pointed end. It should lap over the edge of the declination circle and come almost, but not quite, in contact with with the graduations of the declination circle.

A hole should be bored through the center of the declination axis, K, at a point 5 inches from the declination circle, through which the polar axis is passed. A counter weight must be attached to the end of the stick, K, to balance the

weight of the telescope and the block to which it is strapped. Detach the block and the telescope from the stick, K, and weigh them carefully. Then take an equal weight of some heavy material, such as iron or lead. Lead shot is the best material to use. Get a round flat can with a lid on it, and attach it to the end of the stick by means of a couple of nails driven in on a slant, so that they will run diagonally across the grain of the wood and hence will hold firmly. Place the shot in the can, adding a little to make up for the weight of the bolt and the declination circle, and put on the lid. Then attach the block H and the telescope to the stick, mount the stick on its polar axis and test out its balance. If the counter weight is too heavy, swing the stick up to the vertical position, so that you can take out or add to the shot in the can without spilling the contents. When just the right amount of shot has been determined, take out the shot and melt it in a skillet. Then pour it back into the can after first taking the telescope off the axis and the axis off the mounting so that there will be no danger of spilling metal on these parts and injuring them. As lead is rather expensive, pieces of iron may be used to form the bulk of the weight with enough lead shot added so that when it is melted and poured over the iron it will cement the pieces into a solid mass. Great care should be taken to have the can perfectly dry before the hot lead is poured into it, otherwise there is liable to be an explosion of steam when the molten metal is being poured. If the can is cold and the lead not too hot, it will solidify at once without melting the solder in the seams of the can. If iron weights, such as nails or

bolts are used, they must be heated before being placed in, so that they will not chill the lead too quickly and prevent it from flowing freely around them. Instead of lead, beeswax or resin may be used to bind the mass into a solid lump.

Adjusting the Mounting

Now we are ready to set our declination circle. It should be fastened in such a position that when the telescope is parallel to the polar axis the pointer, P, will point to 90 degrees north. This can be done with a fair degree of accuracy when the declination circle is first applied to the stick, K, and in this position the declination circle is made fast with a couple of tacks or brads, but after the parts have been assembled greater accuracy can be obtained by mounting the axis on a horizontal rod, using a level to make sure that it is perfectly horizontal, and then turning the telescope to horizontal position, too, as determined by the level. The pointer may now be made to point exactly to 90 degrees north by bending it slightly with the pliers.

The stick, K, must carry a pointer, R, to bear upon the graduations of the hour circle. This should lap over the hour circle. Another pointer, S, on the edge of the board, E, should point vertically upward.

Setting up the Telescope

We are now ready to use the telescope and we may proceed as follows: It is best to select some open spot from which a full sweep of the heavens may be obtained and there lay a foundation for the mounting which will save much time in setting up. First put up the tripod with one

leg extended toward the north as nearly as you can determine it, although no great accuracy is required. Spread the legs of the tripod sufficiently to provide a firm base for the telescope. Then adjust the legs until the head lies perfectly level, as shown by a couple of levels placed at right angles on the head of the tripod. Note where the legs of the tripod rest on the ground and at each point bury a brick endwise in the ground. Now set up the tripod again with the points of the legs resting upon the bricks and, after leveling the head once more, mark the spot where each leg bears upon the brick and with a nail and hammer dig a small hole in the face of the brick to receive the nail in the end of the tripod leg. A fine adjustment of the head of the tripod may be had by digging these holes deeper on this side or that as may be needed. Once this is done, the tripod can be set up very quickly and accurately whenever desired. However, it is not absolutely necessary that the tripod point due north, as the equatorial mounting can be adjusted upon it as desired. Neither is it absolutely necessary that the head be perfectly level, because the polar axis can be adjusted by means of the straps, J. However, the less adjustment there is to be done, the handier will be the apparatus and the more time will there be for observation of the heavens.

Having set up our telescope mounting, we must first point the polar axis due north. Unfortunately, the pole star is not directly on the pole of the sky, but we learned on page 84 that it is due north when Delta of Cassiopeia or Zeta of the Great Dipper are directly above or below it. If Zeta is overhead set the telescope with pointer P at

a shade over 1 degree above the 90-degree mark, north, and then with pointer R directly above pointer S swing the board D and raise the board E until Polaris is cut by the cross hairs of the telescope. The boards E and D may now be clamped at this adjustment and the telescope is ready for business.

To check up the adjustment, we may train the telescope on some other star whose position we know. Suppose we take Alpha of the Great Dipper. Its astronomical position is R A 10 h. 58 m. Dec. + 62° 17'. First we shall turn the telescope on the declination axis until the pointer P points to 62 degrees north (we can not bother with minutes on our crude mounting). Then the declination axis is turned on the polar axis until the star comes into the field of the telescope. After the star has been centered accurately in the field of the telescope, turn the hour circle until the pointer R points to XI, which is about as near as we can come to 10 h. 58 m. Then the pointer S will point to the sidereal time. Large telescope mountings are provided with a clock set to run on sidereal time, and this keeps the hour circle turning at the same speed as the heavens are turning, so that once the telescope has been trained on a star it is connected to the hour circle and will automatically keep on all night, if desired, or until the star sets. A clock driven mounting will be a little too complicated for us to construct, but we can get around the difficulty by now and then training the telescope on some star whose right ascension we know and in that way find the sidereal time and set our hour circle correspondingly.

Once our mounting has been properly adjusted, we may cut a mark across the tripod head and board D so that the latter may be brought to the same adjustment another time without having to make observations on the stars. A similar mark should be made on the links J and the board E, so that, should this adjustment be disturbed, it can be restored again with no trouble.

Some Uses for the Telescope

Now that we have all our adjustments made, we can go ahead and use our telescope to search out the wonders of the heavens. The equatorial mounting will be found a great help in locating very faint objects which are barely visible to the naked eye. For instance, there may be an astronomical bulletin published to the effect that a comet has been discovered in R. A. 11 h. 45 m. Dec. —12°7′. We can at once set our telescope to these reference points and bring the object into view. Or maybe we may wish to find one of the more distant planets such as Uranus, which is so far away that it can barely be made out with the naked eye. Being a planet, it is constantly moving through the heavens, although apparently very slowly, because of its immense distance from us and from the sun about which it revolves. The only way to find this planet is to look up its *ephemeris,* as the astronomer would call it; that is, its positions week by week or month by month. Then, after setting our telescope, we can easily bring it into view. Of course, no very great accuracy can be expected from a crude, homemade equatorial mounting such as this, but fortunately the field

of our telescope covers a number of degrees, and the object will be sure to come somewhere within the field despite the inaccuracies of the mounting.

In using the telescope we must not forget that the hour circle refers to time, not mean solar time such as we use, but sidereal time, and that as the time passes, we must keep turning the circle accordingly. Before looking for any new object, it will be well to adjust the position of our hour circle by an observation on a known star.

Unfortunately, there isn't room in this book to tell of all the wonderful sights that are to be seen in the heavens even through a small telescope. You had better get from your library some popular book on astronomy and study that. Of course, the very first thing to look for is Jupiter, if that planet happens to be well placed for observation. Around it you will see a family of tiny moons. If Saturn happens to be favorably located, her rings will form a most interesting sight. The planet Venus will be found to go through phases just like the moon, appearing sometimes as a crescent, sometimes almost as a full disk, depending upon its position with respect to the sun. Of course our own moon is the nearest celestial neighbor we have, and there is a mine of interest to be found in it, particularly when it is not full, for then the long shadows are cast by its mountains and its pitted surface is thrown into strong relief.

Never look at the sun through the telescope, without protecting the eyes with smoked glasses, because the light of the sun, greatly magnified by the telescope, would blind a person instantly if allowed to fall upon the naked eye. The objects of most interest on the sun will be found to be

the great black sunspots that develop now and then. As a matter of fact, they are not black at all, though they seem so by contrast with the brilliant surface of the sun. They are supposed to be storms on the sun which tear open the envelope of white-hot gases with which the sun is surrounded. Aside from the solar system, there are hosts of other interesting objects in the sky. There are the curious nebulæ or clouds of luminous gas and great clusters of stars. The group of stars known as the Pleiades look interesting to the naked eye, but in a telescope even of low magnitude, the group expands into a large number.

What the heavens hold in store for an amateur with a telescope of this size might easily fill the rest of this volume, but this is not a book of astronomy.

CHAPTER IV

SURVEYING, SOUNDING AND SIGNALING

SINGLE-BARREL RAFT. PLANE TABLE SURVEYING. THE ALIDADE. SURVEYING THE POND. TRAVERSING. THE PACE SCALE. HOW TO MAKE AN ODOMETER. FLAG SIGNALING. THE SIGNAL GUN. SOUNDING INSTRUMENTS. CLAMSHELL SOUNDING LEAD. THE SOUNDING SKIPPER. SOUNDING BIG BEAR POND.

As we said in the opening chapter of this book, it is impossible to tell a boy what to make and how to make it, because there is no way of knowing just what material and tools a boy can get hold of. In the same way it is impossible to tell him just what engineering work to do, because there is no way of knowing what particular problem he will have to face. All we can do is to imagine some situation that will afford a good variety of work, and then, if that happens to fit your case, well and good. If not, it will surely give you a hint or two that will help you to handle the particular situation that confronts you.

Now we are going to imagine that we have found a pond in a lonesome spot off in the heart of a woods and that the owner of it has no objection whatsoever of our playing with it, or upon it, or in it. At one side of the pond, the trees come down to the water's edge. On the other side, there is a clearing, but the ground is covered with underbrush. There is a thick tangle of blackberry bushes and some swampy lowland. This is on the north side of the

pond. At the eastern end, the banks are of clay in which boulders are embedded. Here, there is a ridge of rock forming a natural dam that is responsible for the pond. Through the breaks in this ridge, the water makes its way in a number of small streams that join further down. At low water, we can easily make our way across the stream by stepping from rock to rock, but very evidently at high water we shall be unable to do this, and we may find it necessary to build a bridge here. At the west end of the pond, where the stream enters, the water is deep and passes between steep banks. There is plenty of water here for a boat, but a little further up stream navigation is barred by rapids. Maybe we can do a bit of engineering work that will carry our boat beyond the rapids into the deeper water above. We may as well give the pond a name. Suppose we call it Big Bear Pond and the stream Otter River.

Single-Barrel Raft

Before we can do very much with the pond, we must make a survey of it, and before we do that we must have some way of getting about upon it. It will help us to have a boat to carry our surveying instruments from one point to another without having to chop our way through tangles of brush and briars, and then, after making our outline map of the pond, we must get out upon the pond in order to get at the mysteries hidden under the surface of the water.

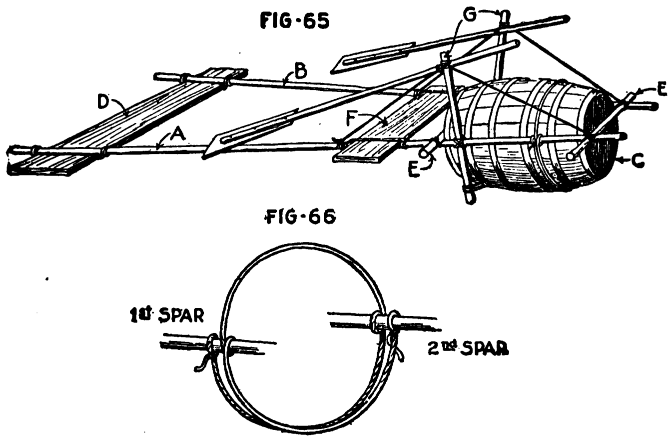
We have got to know, for instance, where the channel is, where there are any flats or any deep holes, before we shall know where to put our dock. For instance, we suspect that a good place to moor our boat is in a cove on the

north side, because this spot is sheltered from the squalls that burst out of the west, and also from the storm winds that drive out of the northeast and the southeast. But will it be possible to get enough deep water here to float our boats, or are there shoals in the way? And if there are shoals, are they of soft mud that can easily be dredged, or is the bottom hard? Maybe there are heavy boulders that bar the entrance to the cove. If so, we had better know about them before we go to the trouble of building a dock at this place. Besides, the bramble patch that surrounds the cove is not a very pleasant tangle to get through, and after sounding the pond thoroughly we may hit upon another spot that will be better for our harbor.

What we need is a boat or a raft to carry us out over the waters and enable us to make careful soundings. Instead of going to the trouble of building a boat at this time, we can build a very good substitute in the shape of a raft, provided we can get hold of a water-tight barrel or a cask. We should make every effort to get hold of such a barrel. It does not matter much whether it has been used for oil or vinegar or cider, just so long as it is perfectly water-tight. We are going to find the barrel useful for other purposes besides that of a makeshift raft.

In the construction of this raft, we shall take a hint from the British military engineers, who sometimes make an emergency raft of this kind to carry a couple of men across the water. Fig. 65 gives a good idea of the design. It is put together without nails, except for the oars, which are made by nailing a flat blade, which may be fashioned out of a shingle, to a stick about 5 feet long. Two spars,

A and B, about 12 feet long, are tied to the barrel, C, and at the opposite end they are lashed to a board, D, about 5 feet long. The method of lashing the spars to the barrel is shown clearly in Fig. 66. The rope is first tied to one of the spars and is then passed under the barrel, where it takes a turn around the second spar. Then it passes over



FIGS. 65 AND 66.—Construction of the barrel raft

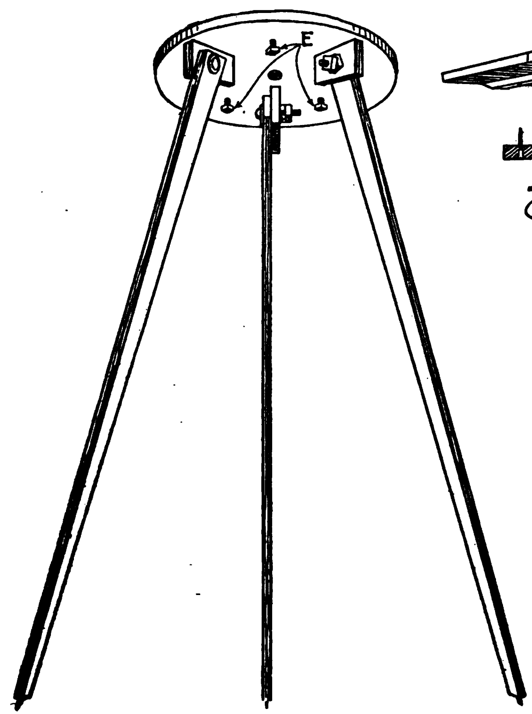
the barrel, taking a turn around the first spar, and, continuing to the second spar, under the barrel, is finally tied firmly to it. At each end of the barrel, cross braces, E, are tied to the spars, and a short board, F, for the rower to rest his feet upon, is tied to the spars near the barrel. The rower sits upon the barrel, and his oars are tied in slings to a pair of upright sticks, G, which are securely lashed to the long spars while their lower ends are tied together by a rope that passes under the barrel. To steady them length-

wise of the raft, they are guyed by means of ropes running fore and aft to the spars.

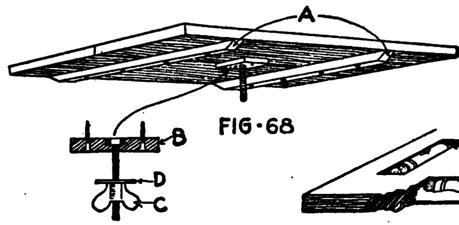
Of course, this is only an emergency raft, but it can be put together in a hurry and will serve to carry us about the pond until we have time to construct something more substantial. As the parts are merely lashed together, the raft can easily be dismantled and the parts are in no wise damaged for use in other work.

Plane Table Surveying

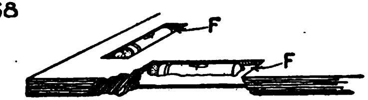
Our next job is to rig up some sort of a surveying instrument. Probably the simplest apparatus for us to use is the "plane table." The plane table consists of a drawing board with which a ruler is used that bears a couple of sights. To carry the drawing board, we must make a substantial tripod. This may be built like the one described in the last chapter, but it should be much shorter. A simpler tripod can be made as shown in Fig. 67. For the tripod head, take the bottom of a peach basket, getting as large a one as possible. There must be three blocks or ribs on the under side of the head to which the legs of the tripod can be pivoted. These should be a couple of inches deep and must radiate from the center of the head, as shown in the drawing, but they must not run all the way to the center, or they will interfere with the thumb nut that is to fasten the drawing board to the tripod. The ribs are fastened to the head of the tripod by driving screws in from the top. The tripod legs are made of strips of wood an inch thick and tapering from 3 inches at the top to 1½ inches at the bottom, and they should be about 3½ feet



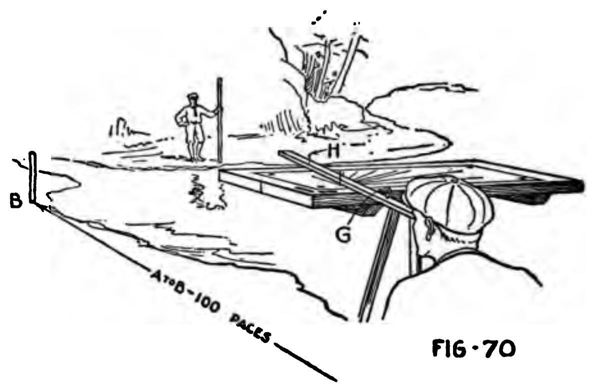
FIG·67



FIG·68



FIG·69



FIG·70

FIGS. 67 TO 70.—Plane table surveying

long. A nail should be driven into the bottom of each leg, leaving the end projecting about ½ inch. Then the head of the nail is cut off with a file, leaving a point that will readily sink into the ground and help to hold the tripod from slipping, particularly when it is being used on hard or rocky surfaces. The legs are pivoted to the ribs under the tripod head by means of short bolts. Each bolt should be fitted with a washer under the head and two nuts. The first nut is turned up on the bolt until the leg is held so tightly that it can be swung on its pivot, but not without considerable friction. Then the other nut is threaded upon the bolt and jammed up against the first one so as to keep the latter from working loose. In the center of the tripod head a hole must be bored for the screw that is to hold the plane table.

The plane table, or drawing board, is made of two carefully selected and well-planed soft-pine boards, straight grained and free from knots. The boards are 1 foot wide and 2 feet long, and they are carefully fitted side by side and fastened to a pair of cleats (A, Fig. 68) so as to form a drawing board 2 feet square. We must be sure to plane the edges of the board true, so that there will be no crack between the boards to catch the pencil and make it break through the paper when the board is in use. The cleats must be fastened by means of screws that are let into the board from the under side and do not penetrate through to the drawing surface. A block of wood, B, with a hole through it ½ inch in diameter and a socket cut out with a chisel just large enough to receive the head of a ½-inch bolt is now prepared. The bolt should be about 2 inches long and should be provided with a wing nut, C, or a thumb nut,

and a washer, D. The bolt is fitted into the block and the block is fastened to the middle of the drawing board on the under side with the body of the bolt projecting outward.

To fasten the board to the tripod, the bolt is passed through the hole in the head of the tripod, the washer is applied to it, and the wing nut is screwed upon the bolt until it bears against the tripod head. It may be well to fasten the washer, D, to the bottom of the tripod head, instead of carrying it on the bolt, and this can be done by driving tacks into the tripod with their heads overlapping the washer.

It is an advantage to be able to fasten the plane table truly level, and so the tripod should be fitted with three leveling screws. Thumb screws should be used about 2½ inches long, and each be provided with a nut. At three points in the upper face of the tripod head, sockets should be cut to receive the nuts. The sockets should be small enough to make a driving fit, which will keep the nuts from dropping out of place when the tripod is being carried about. The thumb screws (E, Fig. 67) are then passed through holes in the tripod head and threaded through the nuts until they bear against the under side of the drawing board. Where the leveling screws bear against the board, it should be faced with tin to keep the screws from crushing into the wood.

The drawing board itself should be provided with two levels running at right angles to each other so that we can determine whether the board is absolutely level. Such levels can be bought for a small sum at any hardware store, but they can very well be made at home out of a couple of

small bottles, such as are used for homeopathic pills. Two slots, F, F, are cut in the drawing board near adjoining edges of the board, one for each level. These slots should be just large enough to receive the bottles. Under each slot a piece of tin is tacked to keep the bottle from falling through. The bottles are nearly filled with water, leaving only a small bubble of air after they have been tightly corked. Then a scratch is made in the middle of each bottle with a sharp file. This done, a bit of putty is placed in each slot and the bottle is pressed down into it. While the putty is still soft, the plane table is trued up with a carpenter's spirit level, and then the bottles are pressed down into the putty at one end or the other until the bubble in each comes squarely under the scratch in the middle of the bottle. Be sure that there is enough putty to overlap the bottles and hold them in. After the bottles have been set, they must be laid aside for a while to let the putty harden.

Now we are ready to set up our plane table. The tripod is set up and the plane table is mounted upon it. Then the tripod legs are adjusted until the table is nearly level. It will be very difficult to get it absolutely level by this means, but after we have done our best with the tripod legs, the thumb screw that fastens the drawing board to the tripod head is loosened and the leveling screws are adjusted until the bubbles in the two bottles are brought directly under the marks scratched in the bottles. This done, the table is truly level, and we are ready to go ahead with our surveying; but first we must have an "alidade," which is a surveyor's name for a drawing ruler with a means for sighting it on an object.

The Alidade

For our alidade, we shall use a yard stick. About 10 inches from one end of the yard stick, thread a small screw-eye (G, Fig. 70) into the wood, being careful to place it right on the center line of the stick. At the far end of the yard stick, drive a pin, H, into the wood right on the center line of the stick with the head of the pin on a level with the middle of the opening in the screw-eye. That is all there is to the alidade. Of course, it can be improved upon by mounting a telescope on the yard stick. The telescope can be built in the same way as the one described on page 88, except on a smaller scale. The objective, for instance, can be a cheap camera lens with a 5 or 6 inch focus, and if the eye-piece has a focus of 1 inch or less, we shall have a magnification of 5 or 6 diameters, which will be ample for our alidade. Of course, there should be cross hairs in the focus of the eye piece so that you can train the alidade upon any distant object with great accuracy by moving the stick about until the cross hairs fall directly upon the object aimed at. But for such rough work as we have in hand, the plain yard stick with screw-eye and pin will serve our purposes very well. The aiming is done by looking through the screw-eye at the object and moving the yard stick until the head of the pin falls upon the object and is at the same time in the center of the screw-eye.

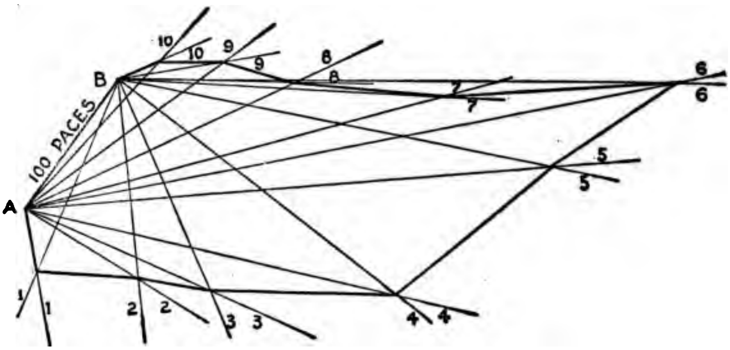
Surveying the Pond

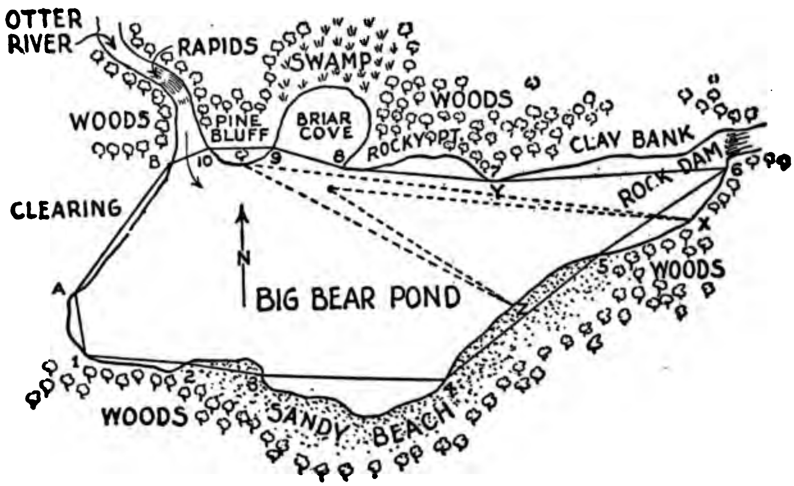
Now we can proceed to survey the pond. This will take two boys, one to operate the plane table and the other to hold the rod on which the sights are to be made. The rodman

must be provided with a bundle of stakes numbered "1," "2," "3," etc., and two long stakes marked "*A*" and "*B*." First, two points are selected along the shores of the pond. from which most of the rest of the pond can be seen. The distance between these two points is carefully paced off, because it is to be the base line of our survey. Suppose we say it is a hundred paces; then the stakes *A* and *B* are driven into the ground at the two points, and while we are about it we may as well put them at an even number of paces apart. Then the plane table is set up over the stake *A* and is carefully leveled up and fastened firmly in place by tightening the headscrew. A sheet of paper is stretched upon the board and fastened down with thumbtacks, or ordinary small tacks, if thumbtacks are not to be had. At one end of the board a pin is stuck into the paper to represent the point *A*. Then the alidade is set on the board with one edge bearing against the pin, and it is trained on the point *B*. The rodman takes up his station at B, using a rake handle for his rod, and the surveyor sights his instrument very carefully upon the rod. Then a line is drawn along the edge of the alidade and a second pin is stuck into the board to represent the point B. Just where this pin is to be placed will depend upon the scale on which we wish to draw our map. If our base line, *A B*, is 100 paces long, suppose we put the pins 5 inches apart. Then each inch will stand for 20 paces and each 1/4 inch for 5 paces. Then the rodman starts out with his bundle of stakes and sets up his rod at various points along the shore of the pond, picking out prominent spots that are visible from the Station *A* and from which he can also see the long

stake set up at *B*. The surveyor, without moving his plane table, trains his alidade on the rod at each station, keeping the edge of the rod against the pin at the point *A*, and he draws lines of the full length of the board along the edge of the alidade toward these stations. The lines are drawn very lightly, as they are merely reference lines and are to be erased later on. At each station, the rodman drives a stake so that he will be able to locate the station again. The stakes are chosen in the order of the numbers they bear, and the corresponding lines on the drawing board are marked with the same numbers (see Fig. 71).

After the rodman has gone the round of the pond establishing the various stations, and the surveyor at the station *A* has drawn all the lines on the board pointing toward these stations, the plane table is moved to the station *B* at the other end of the base line. The alidade is laid against the two pins and the table is swung around until the sights bear upon the staff held by the rodman at station *A*. Then the table is made fast and the rodman makes the round of the pond again, stopping at each station so that an observation can be made from the point *B*. The lines drawn from *B* to these stations are also marked with the same numbers as those from *A*. A dot is made, where lines *1 1*, *2 2*, *3 3*, etc., intersect, and these dots are connected by straight lines. This will give us the main outline of the pond, as shown in Fig. 71. Then all that we have to do is to sketch in the actual shoreline between these reference points, as in Fig. 72, which can be done with fair accuracy without using any other surveying instrument but the eye. On the map, we can indicate the nature of the shores, whether they are





FIGS. 71 AND 72.—The survey of Big Bear Pond

sandy, rocky, etc. Woods are usually indicated by little circles with a stem to each circle and swampy ground by little tufts of grass.

TRAVERSING

It is not always possible to use a base line in making a survey of any large section. Suppose that we wish to extend our map up Otter River. We can not follow all the

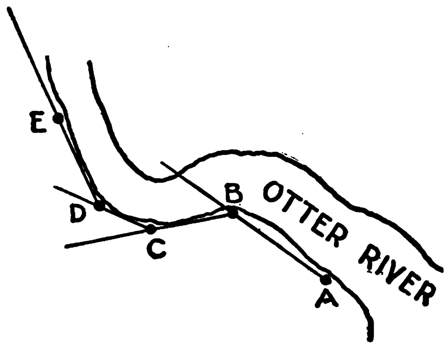


FIG. 73.—Surveying the course of the river

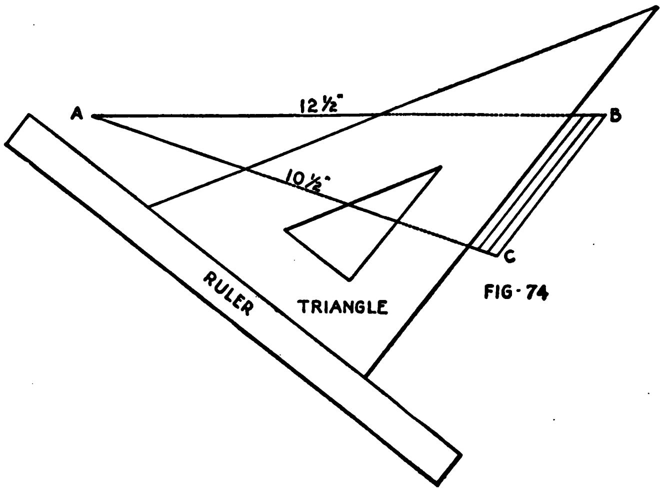
twists and turns of the stream from the end of a base line, and so we shall have to run a " traverse " line, as a surveyor would call it. First we set up our plane table over the starting point (A, Fig. 73). Then we send the rodman up to the first bend in the stream and, training the alidade upon him, draw a line indicating the direction from A to the new post, which we shall call B. Here a stake is driven into the ground and the distance between A and B is carefully paced off. Suppose it is 18 paces. If our map is to be made on the scale of ¼ inch to the pace, we can measure off 18 quarters of an inch, or 4½ inches, along the line from

A, and stick a pin into the board at this point to indicate the post B. The plane table is now moved to post B, and, with the alidade bearing against pins A and B, the table is adjusted until the alidade points back to post A. Then the rodman moves forward to the next bend in the stream and with the alidade bearing against the pin B, a sight is taken on the new post C, and a line is drawn along the alidade to indicate the direction of C on the map. Its distance is determined by pacing as before. And so the work continues, care being taken at each post to sight back to the previous post in order to have the table properly set before taking a sight on the new post.

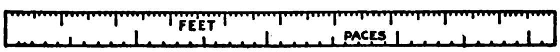
The Pace Scale

When careful surveys are made, distances are measured with a chain or a steel tape-measure whose length has been tested with the utmost accuracy, allowances being made for the expansion and contraction of the metal at different temperatures so that the measurements are true to a small fraction of an inch. It is only when rough surveys are made, such as in sketching a preliminary layout for a railroad, that a surveyor will pace off distances. The paces that different men take vary considerably. The same man will vary his pace at different times, unless he gets into the habit of walking with a fixed stride. It is a good plan to learn to take a steady pace, as this provides a very convenient method of taking measurements. But you must know just how long your stride is so that you can reduce your paces to feet. For this purpose you will have to make a pace scale, that is, a cardboard scale marked with

feet on one side and paces on the other. Measure off carefully, with a tape-measure, a distance of 100 feet and then pace this distance with a natural stride back and forth several times, to find out how many steps it takes to cover that



FIG·74



FIG·75

FIGS. 74 AND 75.—Laying out the pace scale

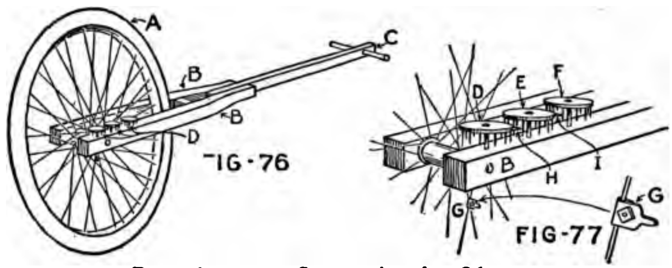
distance. Suppose it takes 42 paces. You can then proceed to make a pace scale. Draw two lines, AB and AC, on a sheet of paper at an angle to one another, as in Fig. 74. Make line AB just 12½ inches long (that is, a hundred eighths of an inch) and line AC 10½ inches long (that is, forty-two quarters of an inch). Draw a line connecting B

and C, then lay off the line AC into 42 equal parts and from each draw a line parallel to BC. This will divide AB into 42 equal parts, and we can proceed to make a rule 12½ inches long divided on one side into a hundred eighths of an inch representing feet, and on the other side into 42 parts each representing one pace (see Fig. 75). To simplify the reading of the scale, every tenth mark should be a heavy one and considerably longer than the rest, and every fifth one only slightly longer than the rest. By means of this scale, paced distance can be translated into feet at a glance.

How to Make an Odometer

A more accurate method of measuring distances is to use a wheel and cyclometer. If you happen to have a cyclometer on your bicycle, all you need to do is to run it over the ground you wish to measure and note the distance recorded in the cyclometer. As most of the distances you will wish to measure will be but a few yards in length, you had better rig up your own measuring apparatus. Fig. 76 shows how this may be done. Take a wheel, A, such as a bicycle wheel, and mount it between the two arms, B, of a yoke, connected to a tongue, C. The exact form of mounting does not matter much, so long as provision is made for the counting wheels, D, which are to record the number of turns the wheel makes. Three counting wheels will be needed, one for units, another for tens and a third for hundreds. These wheels should be about 2 inches in diameter. On the under face of each wheel, there must be two pins or nails driven

into the wood, all equally spaced apart. In Fig. 77, these disks are indicated at D, E, F. On the wheel A is a tooth, G, fashioned out of a piece of brass and fastened to a spoke by means of a screw and nut as shown in Fig. 77. This is adjusted to engage the teeth on disk D. At every turn of the wheel, the tooth G moves the disk D through a tenth of a turn so that the next time the tooth comes around it will engage the next pin on the disk D. The upper face of the disk D is marked with the numerals "0, 1, 2—9." Op-



Figs. 76 and 77.—Construction of an Odometer

posite the zero mark is the pin H, which projects from the edge of disk D in such a position that it will turn the disk E through a tenth of a turn each time it comes around. Disk E is also marked with numerals "0, 1, 2—9," and projecting from the edge of the disk E, opposite the zero mark, is a pin, I, arranged to engage the pins on the disk F. The disks D, E, and F must be stepped one above the other; accordingly they are mounted on long screws which pass through spools, the spools being cut off for the disks D and E, so as to allow for the levels at which they are to be supported. To protect the counting disks from damage, they should be enclosed in a case made of wood, in the top

of which three holes are bored, one for each disk, through which the numbers can be read.

In use, this instrument, which is known to a surveyor as an "odometer," can be wheeled over the distance to be measured, and each turn of the wheel A will be recorded on the disk D. Every tenth turn of the wheel A will be recorded by the disk E, and every hundredth turn by the disk C. With this odometer, we shall need a wheel scale like the pace scale so that turns of the wheel may readily be converted into feet. Just as in preparing the pace scale, the wheel is run over a measured distance of 100 feet, and then the scale is prepared to show on one side the number of wheel turns and on the other side the corresponding number of feet they represent.

Flag Signaling

There ought to be some way for the rodman and the surveyor to communicate with each other, so that there shall be no mistake about the location of the observation stations. If the distances are not very great, they can use megaphones made out of stiff bristol board or pasteboard rolled up into a cone and held in place with paper fasteners. If the pond is of any appreciable size, they will have to communicate with signal flags. There are several different codes for flag signaling, but the one that is most commonly used in these days is the telegraph code, or the International Morse, as it is called. This is given in Fig. 78. The flag is held upright directly in front of the eyes; then a swing to the right stands for a dot and one to the left for a dash. A swing directly forward stands of the end of a word. Now

if, for instance, the surveyor wishes the rodman to move to the left, he will swing his flag once to the left, once to the right, and then twice to the left, to make the dot-dash-dot-

A ·–	J ·–––	S ···	1 ·––––	6 –····
B –···	K –·–	T –	2 ··–––	7 ––···
C –·–·	L ·–··	U ··–	3 ···––	8 –––··
D –··	M ––	V ···–	4 ····–	9 ––––·
E ·	N –·	W ·––	5 ·····	0 –––––
F ··–·	O –––	X –··–		
G ––·	P ·––·	Y –·––		
H ····	Q ––·–	Z ––··		
I ··	R ·–·			

FIG · 78

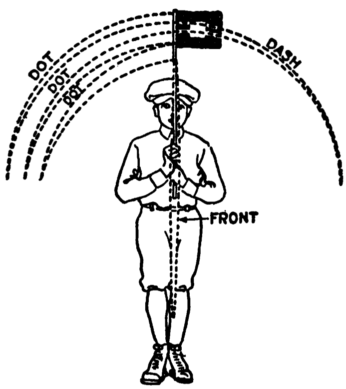


FIG · 79

FIGS. 78 AND 79.—The signal code and how it is used

dot for the letter "L" (see Fig. 79). Of course he can spell out the whole word "left," but it will be much better to make up a code of abbreviations so as to save time and labor.

The Signal Gun

While we are on the subject of signalling, we may as well make a signal gun, with which secret signals can be sent. It may prove handy sometime, when we wish to send a message that we do not want others to read. The signal gun consists of an electric flash lamp mounted in a dummy gun so that the barrel of the gun projects well beyond the end of the lamp. Then only the person at whom the gun is aimed can see the flashes. The gun is held to the shoulder and aimed by means of sights, in the same way that a rifle

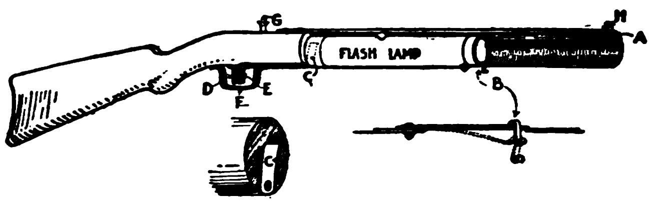


Fig. 80.—The signal gun

is aimed, and the lamp is flashed by means of a trigger. If the gun is accurately aimed, it can be used for signalling in broad daylight, although it will work better at dusk or in the dark. It will be hard, at first, to hold the gun steady enough for the receiver of the message to get the signals, if he is far off, but a little practice will overcome this difficulty, particularly if the lamp is not set very far back from the muzzle of the gun.

Cut out the stock of the gun after the form of a regular rifle. Fig. 80 will give you some idea of the shape of the stock. Get a mailing tube about 8 inches longer than the flash lamp and just large enough for the lamp to fit snugly

into it. Slip the tube over the end of the stock and nail it fast with broad-headed tacks. Uusually, the button with which a flash lamp is operated projects considerably, and so the mailing tube will have to be larger in diameter than the body of the lamp. In order to make the lamp fit snugly, tack a couple of strips of wood, A, Fig. 80, to the tube inside just far enough apart to admit the button of the lamp. The strips should be glued as well as tacked, and the tacks may be driven into the strips from the outside of the tube after they have been backed temporarily with wooden blocks. To hold the lamp in place, a spring latch, B, of brass is fitted into the tube.

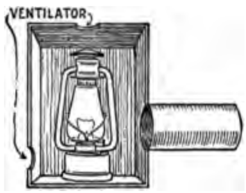
In the common form of flash lamp, there is a metal ring at one end that holds the lens in place and a metal cap at the opposite end to hold the battery in. If these two metal pieces are connected by a wire the lamp will flash. The spring latch, B, which holds the lamp in the barrel, bears against the metal ring at the forward end of the lamp. A plate of brass, C, should be secured to the end of the gun stock so as to make contact with the cap at the rear end of the lamp. In order to make sure that the plate presses against the cap, it should be fastened at its lower end only, and its upper end should be bent forward. This will provide a spring contact piece that will secure a good electrical connection. The trigger of the gun consists of two pieces of brass, D and E, fastened to the stock with screws, and with the ends of the pieces projecting, as shown, about 1/4 inch apart, so that when the finger presses on the piece E, it will be brought into contact with the piece D. The piece D is connected by a wire with the plate C, while the piece E

is connected by a wire with the spring latch B. Insulated electric wire should be used, of the kind employed for electric bells, so that there will be no short circuits should the wires come in contact with each other. In attaching the wires to the brass plates and the trigger pieces, be sure to cut off the insulation and scrape the wire clean at the point of attachment. The connection is made in each case by taking a turn of the wire under the head of the screw that holds the piece in place. To protect the trigger pieces, take a strip of brass and form it into a trigger guard, F, making it fast with a couple of screws.

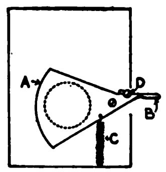
In the stock, just above the trigger, insert a large screw, G, filing a broad V in the head. This will do for the near sight. For the far sight, H, use a small screw and nut, cutting off the screw as much as necessary after testing the gun. This may be done by casting the light of the gun against a barn and noting how tall the sight H should be in order to bring it on a level with the center of the spot of light and the bottom of the V in the sight G. This completes the gun. It will be found very easy to flash the Morse signals with the trigger. The lamp can very easily be taken out of the gun by pulling down the latch piece, B, and then sliding it out of the barrel.

While the signal gun make a portable apparatus, it may be well to know how to construct a fixed, signalling gun, should such a gun be found necessary sometime. For this gun, an ordinary kerosene lantern may be used. This is placed in a box of any suitable form. It does not necessarily have to be light tight, because it is not the lamp that you are concealing, but the signals, and these can only be

read by a person standing in front of the box. Be sure to provide plenty of ventilation in the box. In the front of the box, in line with the flame of the lamp, a hole is cut large enough to receive a tube 2½ inches in diameter. The tube need be only about 6 or 8 inches in length. Fastened to the inside of the box is a shutter of tin, large enough to cover the hole. The shutter, A, Fig. 82, has a piece B projecting through a slot in the side of the box by means of which the shutter may be moved up and down to open



FIG·81



FIG·82

FIGS. 81 AND 82.—Details of the signal lantern

or close the hole. A coil spring, C, should be fastened to the sector in such a way as to hold it normally against the stop D, or in closed position, so that after the handle is depressed to give a flash of light, the shutter will return automatically to closed position. The box should be mounted on a support with a single nail or screw serving as a pivot about which it can be turned to any point of the compass.

Sounding Instruments

In order to make the chart of our pond complete, we must know not only the depth of the water, but the nature of the bottom as well. Mariners usually are provided with

a sounding lead that has a hollow on the under side filled with tallow, lard, or some other sticky substance. When the plummet strikes the bed of the sea, the lard takes up a sample of the bottom, which enables the mariner to determine whether he is sailing over rock, sand, shell or mud. In foggy weather, when the mariner is not sure of his whereabouts, he can sometimes locate his position by examining the specimens picked up by the lead. For this reason, nautical charts commonly indicate the nature of the bottom as well as the depth of the water.

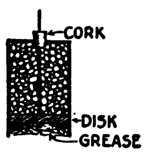


FIG. 83.—Grease-cup sounding lead

A sounding lead of this kind can be made very easily. Take a small tin can, such as a baking-powder can, and punch a hole in the bottom, which is to be the top of the plummet. Cut out a disk of wood just large enough to fit the inside of the can snugly. With a large needle, thread a cork on the sounding line and after passing the line through the hole in the can, screw the cork tightly into the hole.

Now fill the can with pebbles to within an inch or so of the top and fit the disk in place, after passing the end of the line through a hole in the center of the disk. Make a large knot on the end of the line so that it will not slip back through the hole, and then make the disk fast with tacks driven through the sides of the can. The disk keeps

the pebbles in the can, and the cork prevents the lead line from chafing against the sharp edges of the tin. The space below the tin can be filled with grease as indicated in Fig. 83.

The lead line is usually marked off in fathoms by means of tags of leather and bunting. A fathom is 6 feet, but that is too large a unit of measure for a pond, so we shall let the "marks," as they are called, stand for feet instead of fathoms.

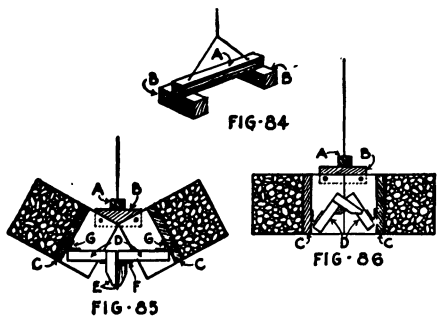
The hand lead line usually has a mark 2, a leather tag; at 3, a piece of blue bunting; at 5, white bunting; at 7, red bunting; at 10, leather; at 13, blue bunting; at 15, white bunting; at 17, red bunting; and at 20, two knots. No tags are placed at the intermediate fathom points which are usually known as "deeps."

Clamshell Sounding Lead

To depend upon tallow to pick up a sample of the ground is, after all, a haphazard way. It is better to use a clam shell scoop like that shown in Figs. 84 to 86.

Get two tin cans, square or oblong in section, of the kind used for corn beef. To a stick, A, nail two wooden blocks, B, each about 2 inches long. The blocks must be far enough apart for the cans to fit freely between them. Hinge the cans to the blocks with long wire nails or pieces of heavy wire. Fill each can about two-thirds full of pebbles and fit in a wooden cover or partition, C, to keep the pebbles in place. Fasten the partitions with tacks driven through the sides of the can. Attach the lead line to stick A. When

the lead is suspending by the line, the weight of the pebbles will keep the cans closed, edge to edge, as shown in Fig. 86, and between the partitions there will be a chamber for the sample. To hold the cans open, hinge two toggle links, D, together and to the partitions. Make the links of wood and use leather for the hinges, F and G. To both links near their common joint, but on opposite sides, nail triggers E, long enough to project below the edges of the cans when they are open, but not so long as to prevent the



FIGS. 84 TO 86.—Clamshell sounding lead

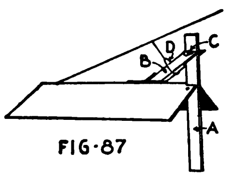
cans from closing. With the toggles set as in Fig. 85, the cans will be held apart, until the triggers are thrown upward by striking the bottom. Then the toggle is sprung, and the cans will close upon each other of their own weight, trapping some of the sand and mud between them.

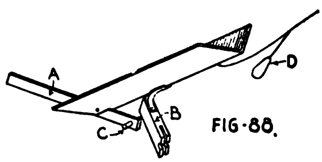
THE SOUNDING "SKIPPER"

A number of years ago, a vessel that was entering the harbor of San Francisco struck an uncharted rock and sank with many of its passengers and crew. There was a

danger spot that none had suspected, a solitary rock that poked its nose up out of the deep water to within a few feet of the surface. Soundings had been taken all about, but the lead had not happened to strike that submerged pinnacle.

It was to discover dangers of that kind that the "skipper" was invented. The skipper is really a water kite, but its action is just the reverse of a kite, for it sinks when it is being pulled through the water and rises when the towing ceases.





FIGS. 87 AND 88.—The sounding skipper

The skipper is set to move at a certain depth, but when it strikes anything—like a sand bar or a submereged rock—a trigger is sprung which causes it to turn over and rise to the surface.

To make a skipper, nail together two thin boards about 15 inches long, to form a V. Fig 87. Cut a saw slot across the peak near the end, and cut away the wood to receive the trigger, A. Mount the trigger on a nail driven through the two boards.

Sharpen the forward edge of the trigger so that it will cut through the water easily. With a piece of leather as a hinge, fasten a stick of wood, B, to the ridge of the skip-

per. Slot the outer end of the stick so as to straddle the trigger, A, and notch it to pass under the pin, C.

Fasten the lead line to the ridge of the skipper near the rear end, loop a wire link, D, loosely over the stick, B, and fasten it to the lead line. Adjust the link so that it will cause the skipper to keep its head down. When you tow this device back of a boat, the water will pile up on the nose of the skipper, bearing it down, and making it ride at a fixed level below the surface. That level will depend upon three things: the speed of the boat, the adjustment of the link, and the amount of line you have paid out.

If, as you tow the skipper, the trigger, A, strikes something, it will release the catch, B, and let the link, D, slip off. The skipper will then turn over to the position shown in Fig. 88 and rise to the surface. You will have to set the skipper by experiment to move at a certain depth. Then it may be towed back and forth all over the pond, and if the trigger remains unsprung, you will know that the whole area traversed is at least as deep as the plane in which the skipper moved.

Although the instruments described above will be found interesting, really the most useful device for sounding a pond, unless it is very deep, will be a long pole marked off in feet. A light bamboo pole, about 8 feet long, will make an excellent sounding rod, but the lower end of it should be weighted with lead so that it will be easier to lower it vertically in deep water. An unweighted rod has a tendency to float which is quite bothersome at times.

Sounding Big Bear Pond

Now that we have our full equipment of sounding instruments, we can proceed to make our soundings and record them on the map. It is easy enough to take the soundings, but quite a different matter to locate them on the map. The simplest way of doing this is to use two plane tables. Make a tracing of the map on thin paper and mount this on the second plane table. Set up one plane table at the station A of the base line, and the other at the station B. Adjust each instrument so that the base line of the map points directly at the other instrument. Then, when a sounding is taken, each plane table man trains his alidade upon the rod of the boy who is making the soundings. The boy at station A draws lines toward the sounding rod from the point A on the map, and the other boy from the point B on the map. Suppose the sounding is 4 feet; the number 4 is signalled from the boat to the shore stations, also the letter " A " to signify that this is the first sounding. The next sounding may be 7 feet and the signal will be " 7B," etc. The plane table men will each mark the signals on the line drawn toward the different sounding positions. After all the soundings have been made, the traced map is put back over the original, and where the A lines cross, a pin prick is made, later to be marked 4. The same is done where the B lines cross, which point is to be marked 7; and so on with all the rest of the lines.

It is not necessary to make the enfire survey of the soundings from one base line. If more convenient, the instruments may be shifted to other posts whose positions are marked on the map.

CHAPTER V

ROADS AND RAILROADS

CORDUROY ROAD. A SIMPLE CABLEWAY. CABLEWAY OPERATED FROM ONE SIDE. A DUMPING SKIP. THE WIRE RAILWAY. WATER-CASK CAR. THE GRAVITY RAILROAD. THE RAILROAD CAR. LAYING THE TRACK. THE STARTING HILL. RAILROAD SWITCH. THE HAND CAR. THE BOY-POWER TRAIN. GATES FOR THE RAILROAD CROSSING. THE TURNTABLE.

OUR first inspection of Big Bear Pond led us to think that Briar Cove would furnish an excellent harbor because it is so well sheltered from storm winds. Unfortunately, our survey shows that the water in the cove is very shallow—too shallow for even a flatbottomed boat. However, that is not a serious obstacle; the bed of the cove is soft mud and we can easily dredge it. It happens that there is a highway north of Big Bear Pond and it runs within 200 paces of Briar Cove. If we build a dock in the cove, we can cut a road through to the highway, which will give us a short and easy approach to the pond. To be sure the road will have to run through marshy ground for a short ways, but this disadvantage is offset by the fact that there are no woods in the way and hence no trees to be cut down.

BUILDING A ROAD

There is nothing very mysterious about building a road such as we shall need. Of course, we cannot attempt to construct a macadam road. That would be too much of a

task and not at all necessary for the traffic we expect to run on it. Suppose we pick out the northwestern side of the cove for our dock, because the land is a bit higher here along the edge of the woods. Then we can skirt the marshy ground most of the way, only having to cross a narrow branch of it just before coming to the highway.

First we shall have to cut down the brush along the line of the road. The road should be at least six feet wide, and to get it straight and of a uniform width it ought to be staked out. At each side of the road, a shallow ditch should be dug for drainage, the earth dug out being piled on the roadway so as to make it a little higher than the surrounding ground. A well-constructed road is "crowned," *i.e.*, it is highest along the center line and curves down on either side. Of course, all mounds must be levelled off and all holes filled in. Maybe we can borrow a lawn roller to pack down the earth.

A Corduroy Road

Where the road crosses the marsh, it is of no use to pile up earth or even stone, because it will simply sink into the mud. We must have a foundation of some sort. We can take the brush that was cut down to clear a way for the road and lay this on the soft ground. Earth can then be piled on the brush without danger of having it all sink into the swamp. A more substantial road is what is known as the "corduroy." It is made by chopping down trees and cutting them into lengths equal to the width of the road. These are laid at right angles to the line of the road and are held in place by "stringers," or logs that run lengthwise of the

road at each side, the stringers being spiked to the road logs. Then the cracks between the logs are filled with earth or small stones. Of course, boys cannot handle big timbers, nor are they often allowed to cut down big trees; but it is quite possible that permission might be had to cut down enough small trees for the short length of corduroy road that we are going to build. As our road is only 6 feet wide, we can get many lengths out of a single tree. At any rate, we shall assume that such permission has been obtained and that the trees we are going to cut are on the south side of Otter River, just across the way from Pine Bluff.

Were it not for the shallowness of Briar Cove, it would be a simple matter to throw the logs into the stream and tow them around to the point where our dock is to be built. As this is out of the question, we shall have to rig up some other way of carrying them. Of course, the logs we are going to use are not heavy and they could be carried by hand, but it will be more like real engineering to rig up some sort of a transportation line.

A Simple Cableway

Our first job is to contrive some scheme for getting the logs across the river. The best plan is to build a cableway. Fortunately there are trees on each side of the river to which we can secure our main cable. If there were no trees, we should have to set up a mast on each bank, bracing it securely with guy wires or ropes, and run the main cable over this to posts driven into the ground.

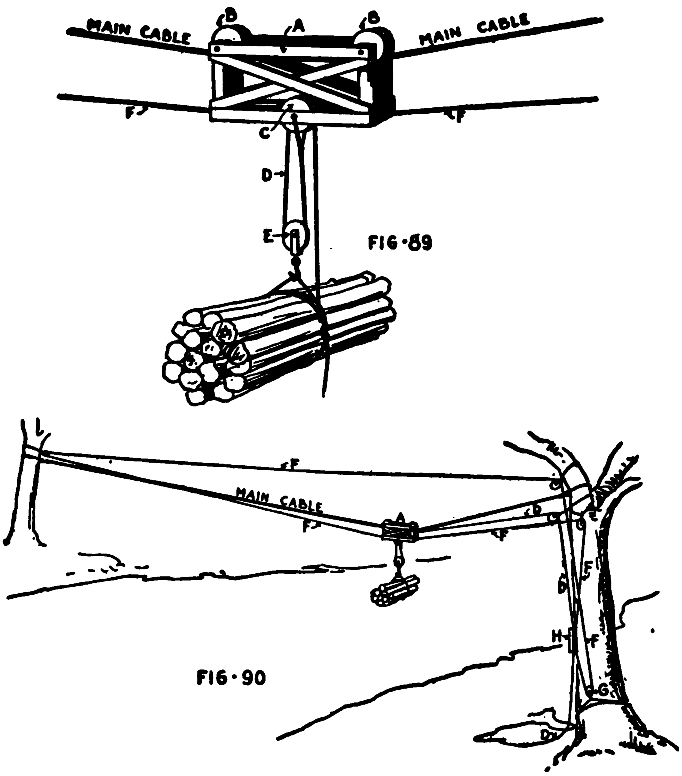
A stout rope should be used for the main cable, and this should be stretched fairly taut from one tree to the other. Fasten the cable about 10 or 12 feet about the ground and well back from the banks of the stream.

On this cable a carriage is to run, the construction of which is shown in Fig. 89. It consists of a wooden frame, A, in which two grooved wheels, B, are mounted. Since we have a lathe, we can turn out these wheels ourselves, otherwise we should have to buy a couple of pulley wheels. They need not be more than 3 inches in diameter. They should be mounted to turn very freely in the frame, and are intended to run along the main cable. At the bottom of the frame, there is another grooved pulley wheel, C, over which the hoisting rope, D, is to run. The hoisting rope is fastened to the bottom of the frame directly under the hoisting pulley whence it passes down through a pulley block, E, and up over the hoisting pulley, C. A hook should be fastened to the hoisting block, and to this the load of logs will be secured, after which it may be hoisted up well clear of the ground and fastened in this position by tying the end of the hoisting rope to the load.

To move the carriage back and forth across the stream, we must have a pair of conveying ropes, F, attached to the carriage and running to the opposite shores of the stream. To keep these ropes from dragging, it is best to have them pass over pulley blocks attached to trees at each end of the cableway.

In use, a boy one one side of the stream hauls the carriage across, while the second boy on the other side pays

out his conveying rope. A bundle of logs is then tied up and hooked to the hoisting block. After the logs have been raised to a height of 4 or 5 feet above the ground and the



FIGS. 89 AND 90.—The cableway

hoisting rope has been made fast to them, the conveying rope on that side is paid out, while the second boy hauls the carriage back over the stream.

Cableway Operated From One Side

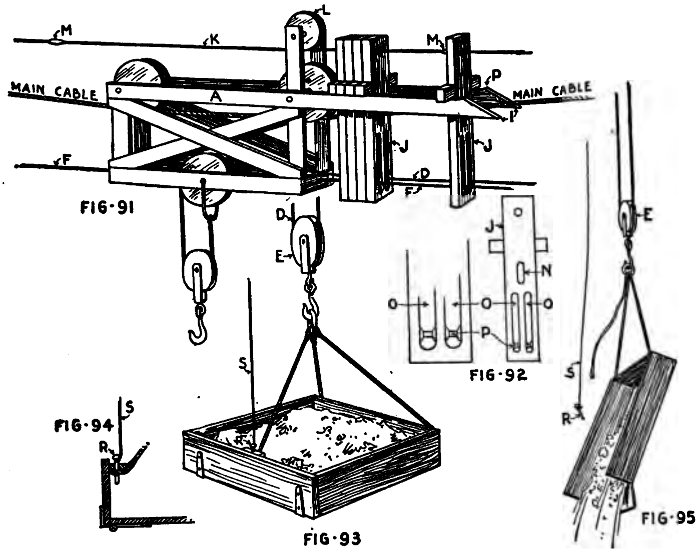
While this is the simplest form of cableway, the rigging can be improved with very little complication so as to have the operations of hoisting the load and moving the carriage all performed from one side. This is done by using an "endless" conveying rope. In other words, the rope runs across the stream above the main cable and is passed around pulley blocks at each end; then the two ends of the rope are fastened to opposite ends of the carriage. At the operating end of the cableway, the conveyor rope passes around a pulley, G, (Fig. 90), near the base of the tree so that it will be within easy reach. With this arrangement, you can either pull the carriage toward you or away from you. There should be a certain amount of slack in the conveying rope so that it can be secured at any position by a couple of turns around a cleat, H, nailed to the tree. The hoisting rope, D, should also run across to the operating end so that the operator of the cableway can let it out or take it in to lower or hoist up the load. When drawing the carriage across, the hoisting cable, D, will have to be paid out or taken in with the conveying rope, F.

One of the difficulties we may have to contend with, if our cableway is long, is the fact that there will be such a long stretch of hoisting rope between the carriage and the operating station that the hoisting block will not run down when we let out the hoisting rope. In other words, the sagging hoisting rope will be heavier than the hoisting block, and so we had better provide a rope on the end of the block by which it may be hauled down.

In the cableways that are used on big engineering jobs, a very ingenious scheme is provided to keep the hoisting rope from sagging too much and dragging heavily on the hoisting block. On the operating side of the carriage there is a projecting bar called a horn. If we are going to construct such a carriage, we had better use two projecting bars, as shown at I, Fig. 91. Suspended between these bars are some supporting devices, J, known as " fall-rope carriers." The construction of these carriers is shown in Fig. 92. Just above the main cable, there is what is known as a button rope, K. This passes under a pulley wheel, L, on the carriage and through eyes in the fall-rope carriers. These eyes are of different sizes, the largest one being in the carrier nearest the carriage and the others being successively smaller. Clamped on the rope, K, there are buttons, M, of different sizes, the one nearest the operating end being the smallest and the others successively larger. Now as the carriage travels out along the main cable, the carriers, J, move with the carriage, A, until the first button, M, is encountered. This passes through all the carriers except the last one, whose eye is so small that it is caught on the button. The second button picks off the next carrier, and so on. In this way, the carriers are distributed at intervals all along the cableway.

As shown in Fig. 92, the carriers have openings, N, in them, through which the main cable passes, and slots, O, through which the hoisting and conveying ropes pass. The carriers hold up these ropes, particularly the hoisting rope. At the bottom of the slots, small spools may be mounted for the ropes to run on. When the carriage is drawn back,

the horns, I, pick up the carriers, one by one. The horns are extensions of the upper frame bars of the carriage and they should be formed with a slight swell, as shown at P, Fig. 91, so as to retain the carriers until they are picked off by the buttons. The button rope does not need to be a



FIGS. 91 TO 95.—Fall-rope carriers and the dumping skip

heavy line; stout twine will do. For the buttons, use lead sinkers of different sizes which can be slit open and then closed upon the twine with a blow of the hammer.

A Dumping Skip

While we are at it, we may as well look into the scheme that is used for operating a dumping skip. The skip is a box in which earth, stone, or rock may be conveyed to any

point along the cableway. Suppose we were constructing a dam across the stream, we would wish to haul rock or earth out to some point in the middle of the stream, and dump it here. Our skip may be constructed as shown in Fig. 93 with one side hinged. It is suspended from the hoisting block by means of three ropes, one of which is caught under a bolt, R, Fig. 94, in the hinged side. A light rope, S, runs from this bolt up over a pulley on the carriage and back to the operating station. By pulling this dumping rope, S, the bolt is pulled out of the skip, letting the skip tip over and the hinged side swing down as shown in Fig. 95, thus discharging the load.

In using this arrangement, care will have to be taken to haul in the dumping rope, S, together with the hoisting and conveying ropes, without pulling out the bolt. When the load has reached the dumping point, give the dumping rope a yank that will pull out the catch and dump the skip.

The Wire Railway

Now that we have rigged up our cableway to transport the logs across the river, the next thing is to find some way of hauling the timber down to the point where it is to be used. Maybe we can make use of an idea that has been used by the French army engineers. The great European War has brought out many ingenious engineering devices and schemes. Men who have suddenly been cut off from home comforts and conveniences have had to put up with whatever they could lay their hands upon. They have been handicapped just as a boy is who cannot buy the tools and

materials he would like to use. This has sharpened their wits and cultivated their resourcefulness.

One of the difficulties that armies have to contend with is that of bringing up supplies, particularly to the trenches that are exposed to the fire of the enemy. A very ingenious scheme was devised by the French to carry supplies to the front through a swampy woods. It would take some time to lay a railroad through the woods; a road bed would have to be graded, banks would have to be cut away, and hollows be filled in. Instead of laying the rails on the ground, somebody suggested that an elevated railroad be built, on which light cars could be pushed along by man power. Stout wooden posts were driven into the ground in two rows, and a pair of parallel wires was stretched from post to post. The cars were fitted with grooved wheels so that they would ride on the wires. Along the wire railway, the brush was cut away to provide a path for the men. Over the swampy places, corduroy roads were laid down to give a good footing. The line was very simply graded by cutting off the posts to the proper level. Of course, there would be slight sag of wires between posts, but this would not matter, for by takng a running start down hill, the climb to the next post could be very easily negotiated.

There is no reason why we should not build a railroad of this kind to carry our logs to the point where they are needed. Of course, the line cannot take a very heavy load, but will convey more than we would care to carry by hand. After it has served its purpose for hauling logs, we can change the course of the line and use it for hauling supplies

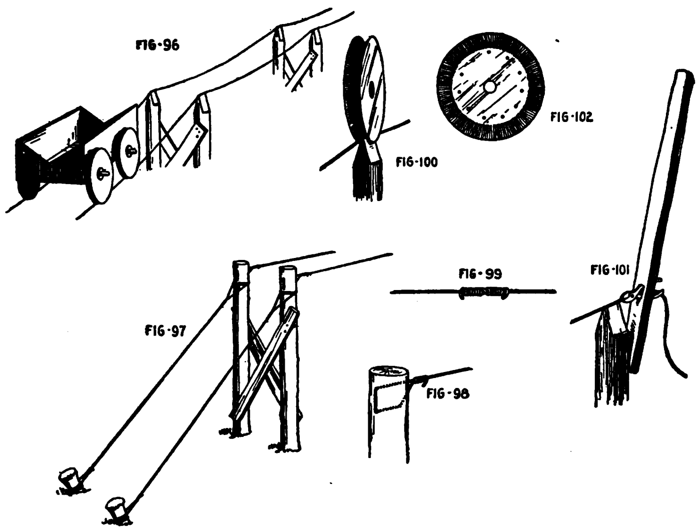
to our dock or from the boat-landing to camp, should we decide to set up a camp near Big Bear Pond.

The best wire for the line is common fence wire of about size No. 12. Of course, the heavier the wire the better, but anything of heavier gauge than No. 12 will be difficult for a boy to handle. The posts that the wires are to run on will have to be set up in pairs at intervals of about 15 feet. The gauge of the railroad, or the space between the wires, should be about 20 inches. It may be difficult to get the posts exactly in the right place, but with some care they should be positioned with fair accuracy. Each pair of posts should be steadied with a diagonal brace or two, as in Fig. 96. After the posts are in place, they should be sawed off to the desired grade. Then the wire is fastened to the posts with staples. The wire will have to be taut—just as taut as it is possible to pull it. This means that the anchor posts, *i.e.*, the posts at each end of the line, will have to be guyed as shown in Fig. 97, to keep them from being uprooted by the pull of the wire, and at curves the posts should slant outward or be guyed with wire to take the pull of the line. Fig. 98 shows how the wire should be secured to the end posts. Splices in the line should be avoided, if possible. If they cannot be avoided, make them as indicated in Fig. 99. The wire is run over a groove in the post, then over a nail in the side of the post, and is fastened securely with staples. Of course, the posts must be chamfered off as shown in Fig. 100, so that the grooved wheels of the car can go over the posts without bumping.

It is safe to say that a boy can hardly draw the wire too taut. It will be sure to stretch and sag in time, but this

is really an advantage, because the more it sags the less likely is it to break under heavy loads. Of course, a sagging line means that the car must do a lot of up and down hill traveling.

However, at the outset, at least, it will be necessary to pull the wire very taut, much tauter than it can be



FIGS. 96 TO 102.—Details of the wire railway

done by hand. Some sort of a wire puller will have to be devised to stretch the wire at each post. A very simple contrivance is shown in Fig. 101. A lever is fashioned out of a strip of wood. In this lever a hole is cut, large enough for the nose of a pair of pliers to pass through quite freely but small enough to catch the handles of the pliers on the outspreading part. The wire is threaded through this hole,

and then the pliers are inserted into the hole and made to grip the wire. The lower end of the lever may be rested against the post as shown and then, by pulling on the upper end, the wire may be drawn as taut as desired. The greater the pull on the lever, the tighter will be the grip on the wire, because the walls of the hole will bear against the flaring handles of the pliers and squeeze them together.

Water-Cask Car

As for the car, this may be merely a box with four deeply grooved wheels to ride on the wire. Fig. 96 shows a special form of car which can be used to carry a cask of water. A railway of this sort will provide a very handy means of hauling water from a spring to camp. The body of the car is merely a box with the end boards cut in the form of a broad "V" to receive the cask. The cask is not to be nailed to the car but merely fitted upon it so that it may be taken off at any time to permit of using the car for other kinds of freight.

The wheels of the car should be turned out on the lathe with a deep V-groove in the edge to run on the wire. If you have no lathe, they may be made out of peach basket bottoms. With a draw knife, or, if that is not to be had, with a good strong jacknife, bevel off the edge of each basket bottom to an angle of about 45 degrees, all around its circumference (see Fig. 102). In order to do this evenly, draw a circle ¾ inch from the edge of the disk and let this define the inner circumference of the beveled edge. This done, nail a pair of disks together with the beveled sides

in, so as to form a V-grooved wheel. In order to make the wheel as strong as possible, see that the grain of one disk is at right angles to that of the other. Be sure to use plenty of nails close to the bottom of the V-groove so that there will be no chance for the wire of the railroad to wedge itself in between the disks.

The time-honored way of attaching wheels to a cart is to use a pair of broom handles for axles. Slip the wheels on, and hold each wheel in place by means of two nails driven at right angles through the axle, one at each side of the wheel. Such a construction will do very well for the wire railway, but rake handles had better be used in place of broom handles, because they are usually of hickory and are far stronger. To keep the axle wheels from digging into the face of the wheel, a couple of big washers of the kind used by plumbers can be fitted between the wood and the nails.

The Gravity Railroad

While we are on the subject of railroads, we may as well try our hand at something a little more ambitious than the wire railroad.

It is too bad that a steam locomotive is so dangerous a toy for a boy to play with—that is, a locomotive large enough to haul him and a few of his friends. As long as a steam locomotive is out of the question, we shall have to get along with something else. Suppose we let the earth do our hauling. In other words, we can build a gravity railroad, something like those that are found at amusement parks.

The banks of Otter River are about 6 feet high. If we build a trestle 10 or 12 feet high on the bank, we shall have a good starting incline to carry our train or car down to the dock.

The Railroad Car

Before we do anything to the railroad, we must build our car and then we can make our track to fit the gauge of the car. Unless we have a lathe, the principal difficulty will be to make the wheels. The bottom of a peach basket will give us a disc about 8 inches in diameter and 3/4 inch thick. This will be altogether too narrow for the tread of the wheel, so we shall have to take two of the basket bottoms and nail them together. When fastening them together, care should be taken to have the grain of one piece lie at right angles to the grain of the other. This will give us a stronger wheel.

Now the wood that is used in peach baskets is of a very inferior kind, and usually the edges of the disks make a very unsatisfactory tread for a wheel. It will be found advisable to put a band of soft iron around the edge of the wheel as a tire.

For the flange of the wheel, we shall have to use a basket bottom of larger size. It ought to be at least 3 inches larger in diameter so that the flange will be 1 1/2 inches deep, and the face of the flange that comes in contact with the rail should be beveled so that there will be no danger of its climbing the rail and running the car off the track.

Now, as the wood of peach baskets is very poor, and as it will be difficult to find a basket bottom of exactly the right

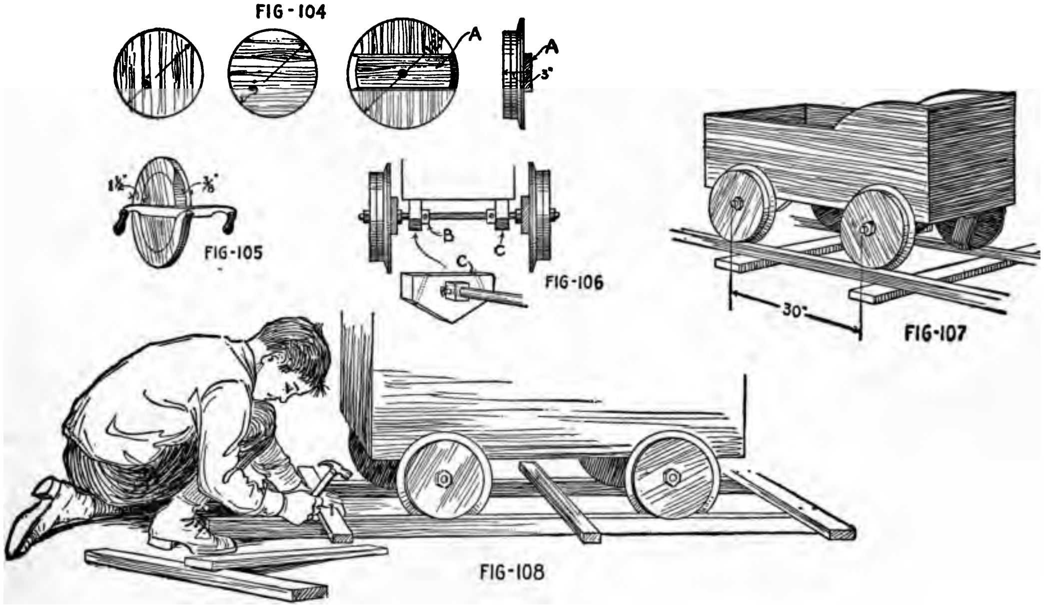
FIG. 103.—Using the wire railway to haul water from the spring to camp

size, it will pay to cut the wheels out of a good pine board. This can be done either on the lathe or with our scroll saw. The board should be ¾ inch thick and at least 1 foot wide, then two disks may be cut out for the tread, each 9 inches in diameter, and one for the flange 12 inches in diameter (see Fig. 104). Place one of the smaller circles on the larger one, centering it carefully, and then draw the pencil around it. Also with a pencil gauge, draw a line around the edge of the larger disk ⅜ inch from each face. In other words, make a pencil mark along the center line of the edge of the disk. Now with the draw knife bevel off the flange from the circle drawn on the face to the center line drawn on the edge, as shown in Fig. 105. When you do this work, you will realize the importance of having a good, straight-grained piece of pine to work with. You will find it advisable to pull the draw knife in the direction of the grain as far as possible. To reinforce the flange, a batten of wood will be necessary, about 4 inches wide and 12 inches long. This will have to be nailed fast to the flange disk as shown at A in Fig. 104, with its grain running across the grain of the flange disk. The batten will have to have its ends shaped to the curve of the flange disk, but this can be done with a draw knfe after it has been nailed fast to the flange. When the wheel is put together, it will be 3 inches thick at the center. This will furnish a good bearing to make a firm attachment of the wheel to the axle.

The hole for the axle had better not be bored until the whole wheel is assembled and firmly nailed together. In a railroad car, the wheels are made fast to the axle and the

axle turns in bearings in the car, because it is very important for the wheels to be kept at a fixed gauge. We had better do the same thing with this gravity car, and then there will be no danger that the wheels may work loose on the axle and wobble enough to run off the track. The best material for our car axles is ½-inch iron rod, or, if that cannot be had, use ⅜-inch gas pipe; this will actually be more than ½ inch in diameter outside. Of course, if nothing else can be had, a round stick, such as a rake handle, will have to be used. The length of the axle will depend upon the gauge of the track. Suppose we use a gauge of 16 inches; that is, a space of 16 inches between the rails; then the axles will have to be about 22 inches long. If a wooden axle is used, the wheel may be made fast to it by running long screws through the batten, A, and diagonally into the axle. The same method might be used with the iron axles, provided a flat spot is filed in the surface of the iron for the screw to engage, or, better still, a hole drilled into the iron for the point of the screw to enter. But, at best, this is not a very secure fastening, and as a bad accident might result from having a wheel fly off when running at a good clip, it will be much better to depend upon a pair of nuts at each end of the axle. The axle should be threaded for a length of about 4 inches. If you are using a piece of pipe, you can get a plumber to do the job for a small sum. Then, with a nut at each side of the wheel, the wheel can be made fast to the axle very securely.

As for the car body, that can be left to your own individual taste and to the resources you have at your disposal.



FIGS. 104 TO 108.—The gravity railroad car

Probably a box can be found that will be narrow enough to fit between the wheels and long enough for a boy to sit in with comfort. Or maybe you will prefer to make the car after some special pattern. At any rate, the wheel base, that is, the distance between the front and rear wheels, should be about 30 inches. The axles should run in bearings of hard wood fastened to the bottom of the car as shown in Fig. 106, and to keep the axles from sliding from one side to the other, a pair of collars, B, should be fastened to them just inside the bearing brackets, C, as shown. These collars may be blocks of wood fastened to the shaft with wood screws bearing against flat spots filed in the axle. The best lubricant for an iron axle turning in a wooden bearing is graphite. Oil will not do, because it will have a tendency to swell the wood and make it bind upon the axle.

Laying the Track

Now that the car is done, we can proceed with the construction of the track. The best material for the rails will be strips of wood measuring 1 by 2 inches and set up on edge. You can get a few boards of 1-inch stuff and have it sawed up at a saw mill into suitable strips. It will not need to be planed. Cross ties should be nailed to the rails every 3 or 4 feet, and the best way to do this is to make the track face downward so that the ties may be laid on top of the rails and nailed down (see Fig. 108). Then, as each section of the track is done, it can be turned over and be fastened in place by nailing it fast to a stake or two driven into the ground. Of course, the car is used as a gauge to be

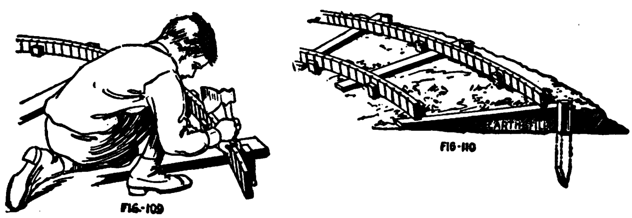
sure that the rails are spaced apart properly. The joints in the rails should not come squarely opposite each other, but should be staggered so as to add strength to the track.

On a gravity railroad, it is better not to use any curves, because it is hard to control the speed of the car and there is too much likelihood of a spill at the turns; besides, a curve is liable to retard the progress of the car. There may be some situations, however, in which a curve is absolutely necessary. Under such circumstances, the wooden rails will have to be bent to the proper shape. It will be found best to make a lot of saw cuts in the face of the rail that is to be on the inside of the curve (see Fig. 109). The cuts should run half way through the wood, and they should be about 2 inches apart. This will make it easier to bend the wood; but to make absolutely sure against breakage, the rails should be soaked in water for a while to make them less brittle. The inside of the curve should have a radius of not less than 10 feet. This should be scratched out on the ground, and then stakes should be driven along the line, after which the inside rail should be bent around the stakes and be held fast by a stake or two on the other side. This done, the outside rail may be bent into place and be held fast as it is bent by connecting it to the inner rail by means of ties. Two or three of the ties may be nailed fast diagonally so that the track section will hold its shape when it is turned over.

It will appear at first thought that the curve of this track section will turn the wrong way when it is turned with the under face up. And so it would, if the section

were turned over sideways. But the turning must be done end for end, which will keep the direction of the curve unaltered. The curve will probably have to be trued up somewhat, but this can be done by means of stakes in the ground to which the ties or even the rails themselves may be fastened.

At the curves, the track should be banked; that is, the outer rail should be higher than the inner one so that the car will lean inward and not have a tendency to upset by



FIGS. 109 AND 110.—Laying a curve in the railway

the action of centrifugal force. The amount of banking necessary depends upon the speed of the car and the radius of the curve, also upon the height of the car body above the rails. Hence, it will be impossible to give exact instructions for the amount of banking necessary, but probably, if the outer rail is raised 4 inches higher than the inner one, it will do for the average conditions. The best plan, and the one that gives the surest foundation for the track at the curve, is to excavate the ground on the inside of the track so that the inner rail will be three inches lower than the outer one. Another plan is to drive a heavy stake into the ground in line with each tie and then, after marking the

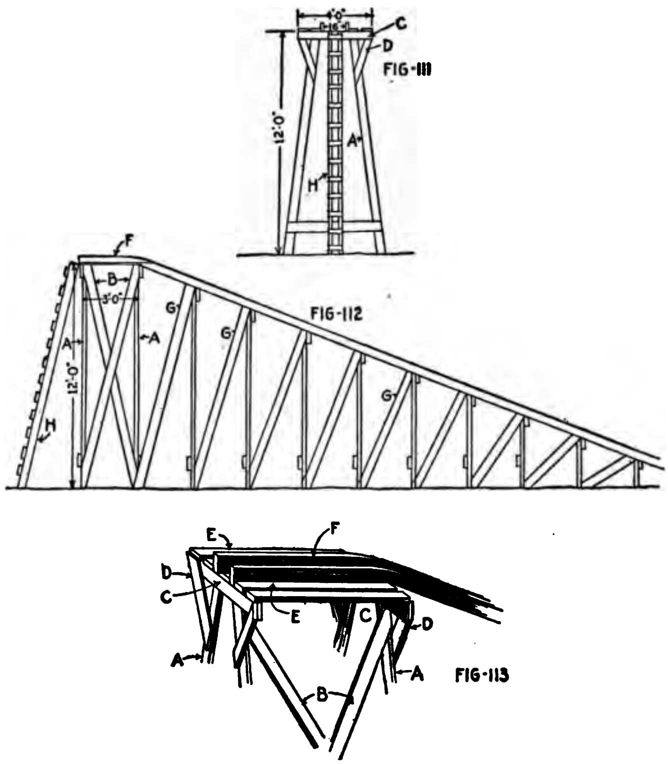
proper elevation on the stake, nail the ties to them. After this, dirt can be shoveled under the ties and tamped under them to support the track properly (see Fig. 110).

The Starting Hill

It is not at all likely that many boys who read this book will have the conditions that we have assumed at Big Bear Pond. Of course, if there is a good hill available, all will be well; otherwise a timber hill will have to be built. If this hill is 12 feet high and some 30 feet long, it should give the car a good start for a run for at least twice this length. The exact length of the run will depend upon the amount of friction on the bearings of the car axles, and on the friction between the car wheels and the rails.

Although 1 by 2 inches is the best size for rails laid on the ground, 1 by 3 inches makes a better size for use in the trestle. First, it will be necessary to build a platform 12 feet high. The construction is shown clearly in Figs. 111 and 113. The lumber used is all 1 by 3-inch stuff. The platform is 4 feet wide and 3 feet deep. Two frames are made, as shown at A, and these are connected by diagonal braces, B. The top member, C, of each frame is extended as shown in Fig. 113, and is braced by diagonals D. On these members the floor boards, E, are laid, leaving a well in the center of the platform for the track. Two pieces of track rail, F, are mounted on the beams, C. These are cut to the shape shown in Fig. 113, with a curve at the far end that will enable the car to swing smoothly from the horizontal position of the platform to the incline leading

down from it. These rails, F, are nailed to the floor boards, E, with their upper edges projecting about 2 inches above the face of the platform.



Figs. 111 to 113.—The starting trestle of the gravity railway

The trestle is supported by uprights 3 feet apart, and there are diagonal braces, G, to take the thrust of the load and keep the trestle from racking. A ladder, H, should

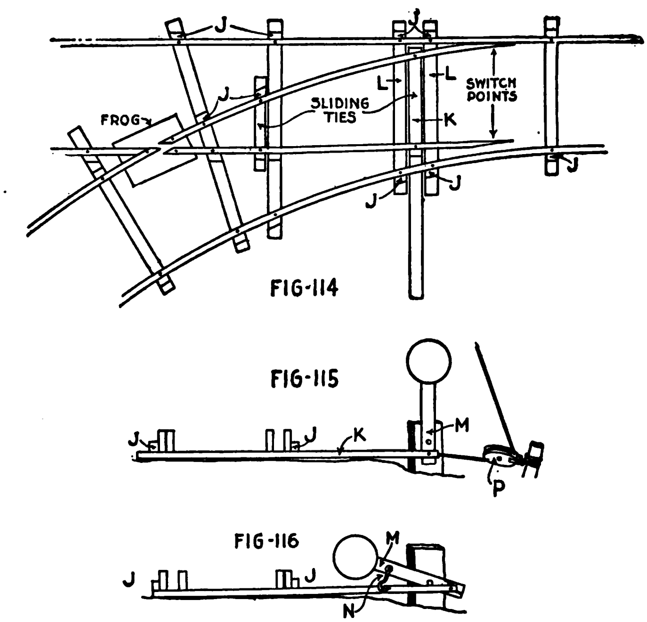
be built at the rear of the trestle to provide access to the platform.

The simplest way to haul the car up the incline is to install a pulley at the rear end of the platform, with a cable that can be extended down the trestle to the car. The car can be run up the incline to the platform by hauling on the rope. If there is a tree overhanging the trestle, a more interesting way of getting the car to the top of the incline is to run a siding on the ground alongside the trestle and then hoist the car up by means of a pulley and rope suspended from a limb of the tree.

Railroad Switch

A switch will have to be put into the track at the foot of the incline, and this may be constructed as shown in Fig. 114. It will hardly be possible to build the track section at the switch face downward. The rails will have to be fastened to the ties by means of long nails driven through them into the ties, and they can be braced by nailing blocks, J, against them and the ties as well. It will be noticed that the switch points are fastened to a movable tie which is arranged to slide between two fixed ties, L. This sliding tie, K, extends about 2 feet to one side of the track and is pivoted to one end of a switch lever, M, which is fulcrumed to a heavy stake driven into the ground. The long end of this lever stands about 15 inches high when it is in the vertical position. It is so arranged that it stands upright when the switch is open to the siding, and it should have a disk of tin painted red, to serve as a warning that the

switch is open. When the switch is closed, it may be locked by means of a hook, N, engaging an eye on the sliding tie. The length of the short arm of the switch lever must be such



FIGS. 114 TO 116.—The switch

as to give a throw of not more than 2 inches to the switch points.

With this arrangement, after a coast down the incline and to the end of the railroad, the car may be pushed back to the foot of the trestle, when the switch will be turned open letting it off the main track upon the siding. From the

end of the siding, it is picked up by the rope and pulley and placed on the rails at the top of the incline. The engineer and passengers can make their way to the top by the ladder. One thing the engineer must guard against before starting his car down the incline; he must be sure that the switch is not turned against him, or an accident will be sure to occur.

An ingenious boy can rig up a scheme for throwing the switch from the starting incline. For instance, a wire attached to the switch lever and passed through a pulley block, P, fastened to a stake, may be extended back to the top of the starting platform, somewhat as shown in Fig. 115.

The Hand Car

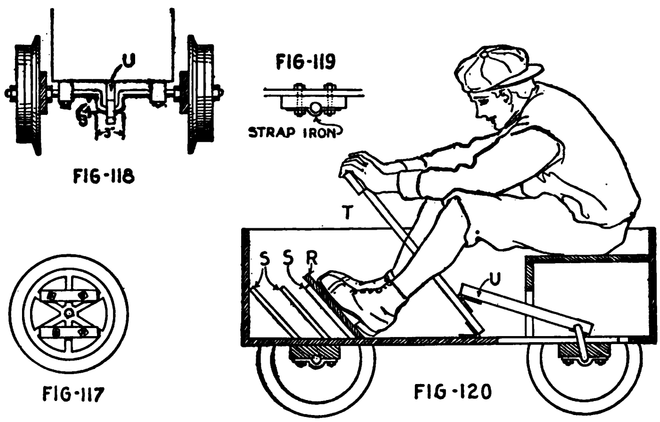
A gravity railroad has a number of disadvantages that may prove very serious to a boy of limited means. The starting platform and the incline require a lot of timber, and there are not many boys who can have all the lumber they need. Then, too, there is another disadvantage, that the car will run only in one direction, that is, down hill, and as far as its momentum will carry it. It always has to be pushed back to the starting point. If only there were some way of making the car go of itself, there would be twice as much fun running it around the track. It ought not to be a very difficult task for a boy to rig up a hand car, and with such a contrivance the inclined track will be unnecessary. The whole railroad can be laid on the ground level, there can be as many curves as may be desired, and switches to sidings or branch tracks.

A very common toy for the small boy, these days, is an "Irish Mail," which is really a hand car that is meant to run on the open road instead of a track. There are plenty of such toys to be had, and if we can get hold of one for our railroad, it will save us a lot of labor. All we need to do is to take our car wheels and fasten them to the Irish Mail wheels with a few bolts and a couple of cleats, as shown in Fig. 117. Then the front axle, which is usually arranged to be steered with the feet, must be fastened so that it will not turn, and our car will be ready for service. Of course, the track will have to be laid after the car is completed, so as to be sure that the gauge corresponds to that of the car.

If an "Irish Mail" cannot very readily be had, it will be a simple matter to make one. Figs. 118 and 120 show how this can be done. The first thing to be done is to find or make a box large enough for the body of the car. The construction will be just the same as in the case of the gravity car, except that the rear axle will have to be bent as shown in Fig. 118, and it is mounted on the bottom of the car in bearings such as illustrated in Fig. 119, so as to form a crank axle. We shall have to use our forge for this, or else call upon the services of a blacksmith. The floor of the car will have to be cut away at the rear, so as to let the crank axle turn freely, but over this opening a seat can be built for the operator of the car. At the forward end of the car, a board, R, is secured across the car, to serve as a foot brace. Just where this brace should be put depends upon the length of the boy who is going to drive the car.

In fact, it may be well to make it adjustable by nailing several cleats, S, to the side of the car against which the board may be fitted.

Right in front of the operator's seat, a lever, T, is hinged to the floor of the car with a stout strap hinge, and a cross bar should be nailed to the upper end of the lever. The



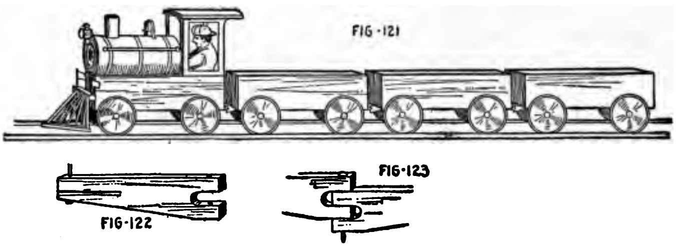
FIGS. 117 TO 120.—Construction of a hand car

length of the lever will depend upon the size of the boy, and so no dimensions are given here. From this lever, a connecting rod, U, will have to run to the rear crank axle. A slot will have to be cut through the floor of the car and the seat box to let this rod through. It will have to be fastened to the lever with a stout hinge, and at the other end it will have to be notched to fit over the end of the crank axle, and then be connected to it by means of a piece of strap iron, as shown. The crank axle will have to have a

throw of at least 3 inches or a sweep 6 inches in diameter, in which case the connecting rod should be fastened to the lever at a height of 6 or 8 inches from the floor.

The Boy-Power Train

If you have gone to the trouble of making your own hand car, no doubt you will wish to make it look like a steam locomotive or like an electric locomotive. Fig. 121 may



FIGS. 121 TO 123.—The hand car train

furnish a suggestion or two. For the smokestack, a piece of pipe of the kind used for rain leaders can be used to advantage, while the boiler may be made of tin or sheet iron or even of roofing paper tacked to a few barrel hoops fastened to the car body. The cars of the train can be made just like the gravity car described above.

To couple the train together, each car will have to have a draw bar hinged close to the axle and projecting about 4 inches beyond the end of the car. The draw bar at the rear end of the locomotive will have to be pivoted to a beam nailed to the bottom of the car body, just far enough back to clear the crank axle as it revolves. Figs. 122 and 123

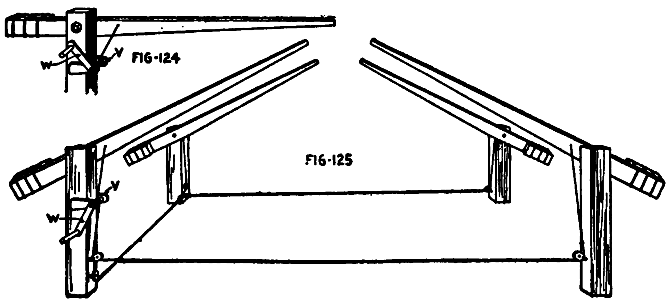
show the shape of the draw bars. Each bar consists of a piece of hard wood about 1 inch thick, and tapering from a depth of 1½ inches at the inner end to a depth of 3 inches at the outer end. In the outer end, a slot is cut to a depth of 1½ inches, leaving two projecting fingers. A hole is bored through these fingers, just large enough to receive a tenpenny nail, which will serve as a coupling pin. The cars are coupled together by bringing the draw bars together, interlacing the fingers, and slipping the coupling pin through the hole in the fingers. A coupling pin should be attached to the draw bar of each car by means of a string so that it will always be at hand when it is wanted.

After the train has been coupled up, draw it around the sharpest curve of the track and note how far to one side or the other the draw bars swing. Then fasten blocks of wood to the bottom of each car to act as stops for the draw bars and keep them from swinging too far to the side when the train is backing.

Gates for the Railroad Crossing

Now that we have a real train with a fair imitation of a locomotive to haul it, we ought to have some of the equipment of a real railroad. Figs. 124 and 125 show how we can rig up gates for crossings. The railroad is sure to cross some path in the yard, and this should be protected by gates. At each side of the path, drive a post in the ground and on this mount the gate arms. These should be light sticks of wood tapering to a point at their meeting ends, while at the opposite ends they should be counter-weighted

with a brick or a stone tied fast. The counter-weight should be heavy enough to raise the gate so that after they have been pulled down by the gateman, they will rise of themselves when released. A simple rig for closing the gates can be made as follows: On one of the posts secure a couple of brackets, V, as shown, and through holes in these brackets mount a roller, which may be a piece of broom-



FIGS. 124 AND 125.—Gates for the railroad crossing

stick or of a shade roller. A crank, W, may be secured to the roller after the manner indicated. Then a stout cord fastened to the gate arm close to the post is wound about the roller, and by giving the crank a few turns the gate arm will be hauled down. Another cord should run from the roller down under a pulley at the foot of the post and thence across the path to the opposite post, where it must pass under a pulley and up to the other gate, so that when the gateman turns the crank, both gates will be lowered at the same time, and when he releases the crank, both gates will be opened at the same time by their counter-weights. To

protect the cord running across from one gate to the other, it may be run through a piece of gas pipe or through a ditch covered by a board. Usually, gates are provided on each side of the track and all four gate arms can be operated by one gateman by a suitable rigging of cords and pulleys such as indicated in Fig. 125.

The Turntable

Another equipment that we should have for our railroad is a turntable for the locomotive. Take two boards

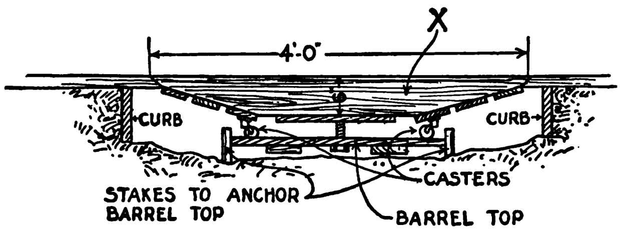


Fig. 126.—The turntable

four feet long, or a little longer than the locomotive, and of about the shape shown at X in Fig. 126. It will be noticed that they are about 6 inches wide at the middle and taper down to 2 inches at each end, where they are cut off on a bevel of about 45 degrees. These two boards are connected to each other by means of boards that space them apart to the exact gauge of the track. A shallow well is dug in the ground to receive the turntable. For the base of the turntable, the top of a barrel is used, the boards of which are held together by nailing a couple of battens to them. In the center of the barrel top, a bolt is inserted to

serve as the pin upon which the turntable will swivel. This bolt passes up through a hole in the bottom of the turntable and is fitted with a couple of nuts, leaving just enough play for the turntable to turn without too much freedom. Then under the turntable four casters are mounted to run on the barrel top. The adjustment of the turntable to its base may be made before the whole is fitted into the well. When fitting the turntable and its base into position, care will have to be taken to bring it into perfect alignment with the track at each side. The track and the turntable will have to be cut on an angle of 45 degrees so that the joint between them will be perfectly smooth. Earth will have to be filled in under the barrel top to bring the turntable to the proper level, and then the barrel top will have to be secured by nailing it to stakes driven into the ground. To keep the well from caving in under the ends of the tracks, it will have to be curbed with a couple of boards.

No doubt there will be many other equipments that will occur to the boy who has followed out the plans given above, such as signal posts, water towers, automatic bells at crossings, etc.; but each boy can work these things out for himself.

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CHAPTER VI

NAVIGATION IMPROVEMENTS ON BIG BEAR POND

ROCKY POINT LIGHT. THE FLASHING LANTERN. THE SIPHON FEED. FILLING THE WATER CASK. THE CHAIN OF POTS. THE BELT STRETCHER. CHINESE WATERLIFT. THE TREADMILL. THE BUCKET DREDGE. CONSTRUCTION OF THE SCOW. THE DREDGE DERRICK. THE DERRICK BOOM. THE SWIVEL TABLE. HOISTING DRUMS. THE CLAMSHELL BUCKET. THE DUMPING SCOW. DREDGING A CHANNEL INTO BRIAR COVE.

In our survey of Big Bear Pond, we found that at the end of Rocky Point there is a hidden boulder about 50 feet from the shore that is not covered by enough water to let a boat pass over it in the summer time when the pond is low. This rock, which is indicated on the map, is a danger spot that must be marked in some way. A buoy would do for a warning by day, but if we expect to be out on the pond at night, we must have a light to mark the danger. As this spot is visible from almost every part of the pond, we may as well build a lighthouse here so that it can be used as a guide to navigation all over the water. Across the cove from Rocky Point is Pine Bluff, where we must have another light to mark the entrance to our harbor. Now when we look at these two lights from the eastern end of the pond, we are liable to mistake one for the other if they

are both elevated to about the same height above the water. From a point, X, Fig. 72, the two lights would look about the same as they would from the point Z, if we were unable to distinguish one light from the other. Of course, the light on Rocky Point would be a little brighter than that on Pine Bluff, because it is a little nearer to us, but we must have a more positive way of distinguishing one light from the other. The only thing to do is to make one or other of these a flashing light. Then there will not be the slightest danger that when you are out on a particularly dark night and try to get your bearings from the point X you will make the mistake of supposing that you are at Z and run the risk of driving your boat aground on the shore at Y.

Rocky Point Light

We had better put our blinking light at Pine Bluff, because it will be easier to get at it for control of the mechanism that we shall have to install here, and we can get a better foundation for it. The Rocky Point Light may be merely a tripod tower built of poles about 15 feet long, braced as shown in Fig. 127, with a platform near the base and provided with rungs on one side, so that it will be possible to climb to the top of the ladder if necessary. The tripod should be set with one of the three legs pointing to the north and the other two to the southeast and the southwest respectively, so that they will interfere as little as possible with the light of the lantern which is to be hung from the top of the tower. An arm is nailed to the top of the tower that overhangs the south side from which the lantern

is suspended. In order to be able to tend to the lamp, we shall have to fasten a pulley to the end of the arm and fasten the lantern to the end of a rope that passes over

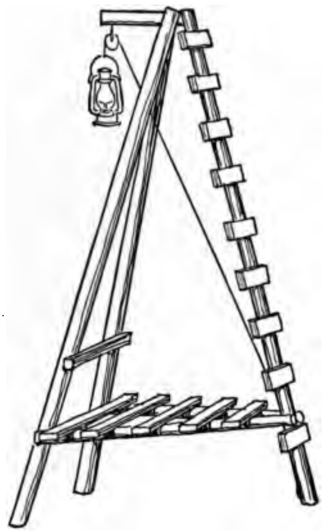
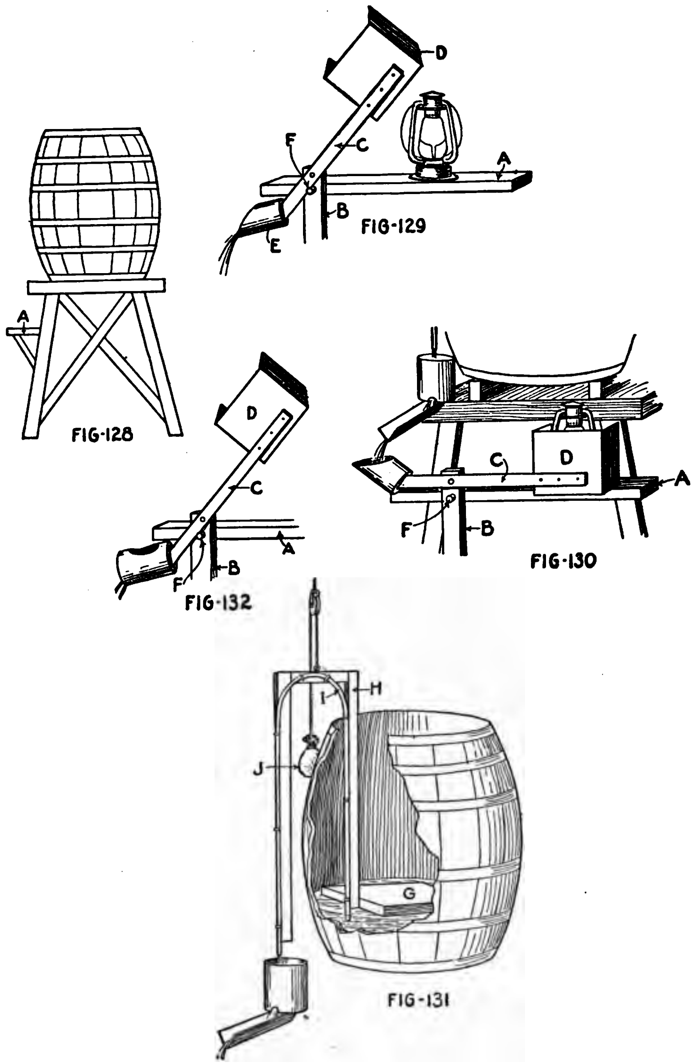


FIG. 127.—The fixed light at Rocky Point

the pulley and runs to the bottom of the tower. Then the lantern may be lowered to fill it and light it at dark.

THE FLASHING LANTERN

To make the blinking lantern, we shall need a cask to hold water, because our flashing mechanism is to be operated by a water motor. As Pine Bluff is fairly high, we shall not need a tall tower for this lantern. All we need to do is to build a platform (Fig. 128) about 5 feet high so as to clear bushes and undergrowth. It will have to be a



FIGS. 128 TO 132.—Details of the flashing light

stout platform, because it is to support the cask, and a cask full of water is rather heavy. Directly in front and a trifle below the bottom of the cask, a shelf, A, is built on which the lantern is supported in such a position that it can be seen from pretty much all of the pond. To one side of the shelf, a post, B, is set up to provide the bearings for a rocking arm, C. At one end, this arm carries a piece of tin, D, that serves as a shutter to cut off the light of the lantern, while at the other is a tin can, E, which is cut away after the manner shown in the illustration, Fig. 129. This can be done with a pair of tin shears, and even, after a fashion, with a can opener, although in the latter case the result will be rather ragged. The end of the arm is cut off at an angle of about 45 degrees, and the bottom of the can is secured to this bevelled end so that it will hold the most water when the arm is horizontal; but when the arm is tipped up at an angle of 45 degrees or more, the water will all spill out. The tin shutter on the opposite end of the arm should be bent to such a form that it will partially enclose the lamp and cut off its light from most of the pond when it is in the lower position.

Now the way the flashing mechanism works is this: The arm is pivoted at such a point that the shutter will overbalance the can when the can is empty. A fine stream of water from the cask is fed into the can, and in time it becomes heavy enough to overcome the weight of the shutter, swing the shutter up, as in Fig. 129. This uncovers the lamp, letting it send out a gleam of light. In the meantime, the water pours out of the can, and as the shutter side is now heavier, the lever is swung back to its original position,

covering the light again, as in Fig. 130. On the return of the lever, the can again comes under the stream of water from the barrel, and again it fills, repeating the operation. In this way, the lantern will be kept flashing as long as there is any water in the cask to keep the mechanism going. A stop pin, F, keeps the lever from swinging too far up while the can is emptying. The nearer the arm swings to the vertical position, the longer will it take for the arm to recover its normal position after the can has emptied, and the more pronounced will be the blinking of the light. For the same reason, the shutter side of the lever should not be much heavier than the can side, and the less the difference in weight between the two, the less water will be required to work the mechanism. Instead of having a tin shutter, a piece of red celluloid or glass can be used, which will give the light a red gleam with a white flash every so often.

The method of feeding the water into the can is likely to prove troublesome. If a tiny hole is bored into the side of the cask close to the bottom, the water will come out of the hole in a solid stream of considerable pressure while the cask is full, but when the water level in the cask is low, there will be nothing but a slow drip from the same hole. This means that when the barrel is full, the flashing mechanism will run faster than when the barrel is nearly empty. Of course, this does not matter very much so long as the light flashes often enough. However, it will not do to let the stream of water strike the can directly, or it may have force enough to drive the lever down without filling the can. The jet of water must first strike a baffle of some sort to break its force; or, better still, there should be another

can to catch the water directly from the barrel, and this can should have a hole in it from which the water may drip into a trough leading to the can on the lever. Instead of depending upon a mere hole in the barrel, it would be much better to use a small stop-cock, if such a thing is to be had. The stream can then be regulated to a nicety,

The Siphon Feed

Another way of dealing with the feed of water is to use a siphon. Probably every reader of this book knows that water can be made to flow through a tube up over the edge of a barrel, provided the tube is first filled with water and the end of the tube on the outside of the barrel is lower than the level of the water inside. The velocity of the stream flowing out of the tube will depend upon the "head" of the water; that is, the difference in level between the inside end and the outside end of the tube. And so all that we need to do is to make a siphon that will float and sink down into the barrel as the level of water is lowered. Then there will always be a constant flow of water until the barrel is empty. With this constant flow, we can keep the intermediate can full, and out of that there will always be a steady flow of water into the can on the lever.

Fig. 131 shows how to construct such a siphon. A 1-inch board, G, just large enough to enter the barrel without hitting the sides, will serve as the float. Secured to one side of the float is a stick of wood, H, to which a fine rubber tube, I, is fastened with staples. Care must be taken not to drive the staples in so far as to block the tube. This stick must be long enough to reach to the bottom of

the barrel. At its upper end, the stick is fastened by means of a crosspiece to a second stick of equal length that is to come on the outside of the barrel, and the tube is carried down this stick to a point just a little below the level of the float inside the barrel. As the siphon will weight one side of the float rather heavily and tilt it so that the sticks are liable to bind against the side of the barrel, we shall have to use a counter-weight to hold it up. A light cord should run over a pulley or a spool mounted on an arm projecting above the barrel, and a small bag of sand, J, should be attached to the other end of the cord. The sand bag should be just heavy enough to keep the float level, but not so heavy as to prevent the float from going down with the falling water.

All this mechanism is rather delicate and liable to be disarranged by the weather, and if anything should be weather proof, it ought to be a lighthouse. So we shall have to enclose all the mechanism, boxing it in in any fashion that suits our convenience, but with the side walls of the casing removable so that we can get at the inside to mend any trouble that may develop.

With the can on the lever as now arranged, the lantern is dark or shows a red light most of the time, and only occasionally does it send out a flash of white light. To make the flash last longer, the can may have only its side cut away, as shown in Fig. 132. At the outer, lower end of the can, however, there must be a hole, so that when the lever is tipped the water will slowly drip out of this opening.

While the mechanism here illustrated is arranged to keep the lantern normally dark, it will be a simple matter to

change it so the light will be normally uncovered and will blink when the can fills. This is done by setting the can on the lever in such a way that it fills when the lever is slanted upward and empties when the lever is horizontal. The shutter will normally lie below the lantern, but will be swung up to cover the light, while the can is emptying.

Filling the Water Cask

Now that we have built our lighthouse, the next task is to find a simple method of filling the cask with water. To attempt to carry pails of water to the top of the tower will be a tedious operation, and the cask must be filled each night or it will not run a very long while. If the cask is to be filled by the pailful, we shall have to rig up a pulley and tackle to haul the pail up. A pail of water is rather heavy, and so we must have a substantial support for the pulley. The best plan is to rig up a couple of posts with a cross bar at the very edge of the bluff and hang our pulley to this (see Fig. 133). Then we must have a rope long enough to form an endless belt reaching from the pulley to the water. Before tying the ends of the rope together, the pail is fastened to it, and the rope is passed through the pulley. Just below the pulley, there is a trough which leads to the cask. This trough is made of two boards nailed together at one edge so as to form a V. A more elaborate trough can be made of three boards, using one board for the bottom and the other two for the sides so as to form a square channel for the water to flow in (see Fig. 134). At the pulley end, this trough must just clear the pail of water as it is drawn up, and the end of the trough must be closed with

a board. A large hook must be screwed into the upper edge of this board, so that when the pail is hauled up, the hook will catch the rim of the pail and tip it, emptying the contents into the trough.

An ordinary pail is designed to keep from upsetting, which is the very thing that we wish it would do, here. The bail or handle is pivoted to the pail as high as possible. In order to bring the pivot above the rim of the pail, a couple of ears project from the top of the pail, and in these the bail is pivoted. The weight of water is all below the pivot, and so there is no danger that the pail will turn over. In fact, if we try to empty the pail by pulling down one edge while holding it up by the bail, we shall find that it puts a heavy load on the hand that is holding the bail. It would be must easier to tip the pail if the bail were pivoted lower down, and so we had better arrange our pail with the bail pivoted about a third of the way down from the top. A new bail will have to be made large enough to reach as far down as that without striking the rim of the pail. This can be made out of stiff wire such as is often used for barrel hoops. As the wire is rather heavy, it may be difficult to bend it, but by softening it in the forge it can be hammered and bent into shape very easily. The boy who has learned how to use the forge can make a ring of heavy wire that will fit snugly around the pail at just the proper height, and he can bend the wire to form a couple of rings for the bail to hook into, as shown at A, Fig. 134. This, however, is a rather difficult job, and we shall find it much easier to support the pail in a rope sling and fasten the bail to that, as illustrated in Fig. 135. The usual sling for a pail

that has no handle will hardly do in the present case, because the pail is liable to slip out when it is tipped over. So we must tie a rope fast to the rim of the pail at the ears and pass it under the bottom with a second piece of rope around the pail at right angles. Where the ropes cross, they must be tied together with light twine. The bail is hooked in a turn of the first rope at the point where it crosses the second.

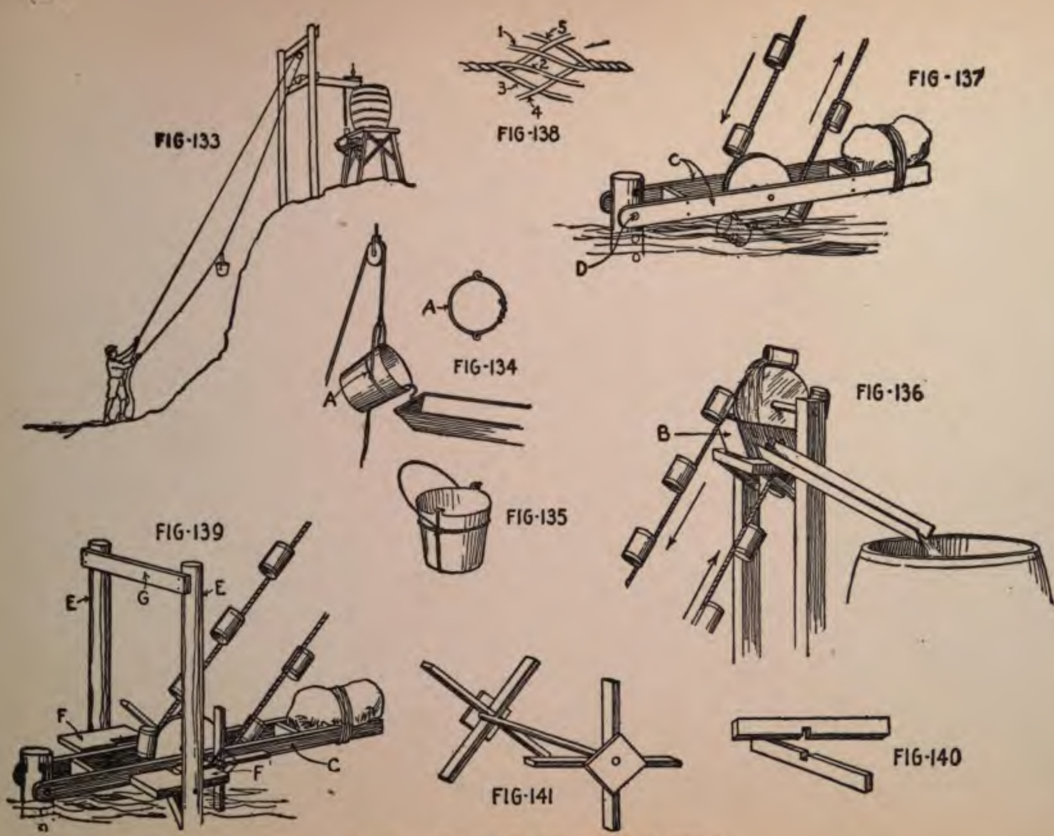
If the pail is hauled up rather gently, when it reaches the trough it will be possible to empty it into the trough without spilling the water to the ground. By having an endless belt instead of a single fall of rope attached to the pail, we can guide the pail past any bushes or projections from the bluff and also make sure that it is caught by the hook on the trough.

The Chain of Pots

While we are building an apparatus for delivering water to the cask, one pail at a time, we might just as well go a step further and build what used to be known as a " chain of pots," that is, a series of pots or buckets attached to the belt which run in a steady procession, full of water, up one reach of the belt, and come down empty on the other reach. We can use tin cans for the buckets, and although each one holds but a small fraction of the amount of water in a single pail, yet there are so many of them, and they run so continuously, that we can fill the barrel in shorter time than with a single pail. With a chain of pots, there is no delay while hauling the cans down to be filled, because there will always be cans on the way up full of water while the

empty ones are coming down. Besides this, the chain of pots will be easier to operate because the empty cans on one side will counterbalance the weight of the cans on the other side, and there will be only the weight of the water to consider, which will surely be less than that of a pailful of water, unless the belt is a very long one. Another advantage that the chain of pots will give us is that it does not have to run straight up, but may be slanted to a considerable angle so that the cans will empty into a trough very close to the cask.

To construct the chain of pots, we shall need two large pulley wheels, with V grooves for the rope belt to run in. These pulleys ought to be about 1 foot in diameter and one to carry the rope over the trough while the other carries it under the water. The upper pulley should be mounted on a shaft made out of a round stick of wood supported between two uprights, as shown in Fig. 136. Between these uprights there is a basin to catch the water that pours out of the cans. This basin may be constructed of wood after the fashion illustrated at B in Fig. 136. The sides of this basin reach up as far as possible around the pulley wheel without interfering with the rope belt, and if the belt is to run on a slant, as indicated in the drawing, the basin will have to have one side higher than the other so as to be sure to catch all the water that pours out of the cans and not let any of it splash out. With a slanting belt, the cans will have to come up filled on the under side of the belt, and on this side it will not be necessary to have the basin so high, but the side of the basin can be raised on the opposite side where the water pours out as the cans turn over the top



FIGS. 133 TO 141.—Water-raising machinery

of the pulley. In the side of the basin, a hole is bored through which the water pours into the trough and thence into the cask.

The Belt Stretcher

There is bound to be a good deal of stretch in a rope belt, particularly one that has to run through water, as this one will, and we must provide something that will take out the slack in the rope. This can be done very well by mounting the lower pulley on a weighted arm. We shall have to excavate a basin in the bottom of the pond close to shore, with a channel leading to it, so that there will always be enough water here to supply our lighthouse reservoir, no matter how low the pond may be. Then we shall have to drive a substantial post that can be used for the fulcrum of the lever that is to carry the lower pulley (see Fig. 137). This lever can be made of two strips of wood, C, spaced far enough apart to let the cans pass between them without the slightest danger of catching. The pulley is mounted between these arms. The arms should be about 6 feet long, and the pulley should be located about midway of their length. Through the post, two or three holes should be bored, big enough for the pivot pin, D, of the lever to be driven tightly into them. In the two strips of the lever, however, the pivot holes are made a little larger so that the lever will turn freely on the pin. The outer end of the lever must be weighted with a rock firmly lashed on. The weight of the rock will keep the rope belt taut. The lever can be adjusted for variations of the water level and for big changes in the length of the belt

by moving the pivot pin, D, into an upper or lower hole in the post.

For the water pots, we can use tomato cans or any other kind, but for the sake of looks they should all be alike and should be cut off neatly at the top. They should be set about 1 foot apart on the rope, to which they can be attached by means of soft iron wire, the kind that is used to hold up stove pipes. A turn of the wire is taken around the rope and then it is passed around the can and back around the rope, where it is drawn very tight by twisting it with a pair of pliers. The can should be lashed in this way to the rope at the top and the bottom so that it will be sure to lie securely on the rope. If this is neatly done, there will be no danger that the can will come loose. To make doubly secure, the wire may be passed through a couple of holes in the upper edge of the can. The wire and the tin can are liable to rust very quickly. Of course, tin does not rust, but tin cans are really made of thin steel plate coated with tin, and the tin is seldom thick enough to keep the water from getting through to the iron underneath and attacking it. And so it will be advisable to protect the cans and the wire that holds them with a good coat of paint.

Care should be taken to fasten the cans on the outer side of the belt, and, to make sure of this, it will be well to put the belt around the pulleys stretching it with the weighted lever and running it around the pulleys a few times so that it will adapt itself before the cans are applied. The lashing of the cans can be done to advantage without taking the belt off the pulley and while it is drawn taut. The manner of fastening the two ends of the rope

together is important. It will not do to tie the rope, for this will make an awkward knot that will not run smoothly over the pulleys and may even have a tendency to throw the belt off the wheel. The rope will have to be spliced. This is not as difficult as may appear at first sight. The ends of the rope are unraveled for 2 or 3 inches, and then they are brought together with each strand of one rope coming between two of the other, as in Fig. 138. The two ends are jammed together. Now we must use what a sailor calls a *marlin spike,* which is nothing more nor less than a sharply pointed stick. Each strand is now passed over the strand directly opposite and tucked under the next one which is lifted up by means of the marlin spike. For instance, strand *1* goes over strand *2* and under strand *3*; strand *4* goes over strand *3* and under strand *5*, etc. When this has been done all the way around, the free strands are all drawn taut and are passed again under the second turn of the standing part of the rope. Then the free ends are raveled out and half of each strand is cut away so as to reduce the thickness of the splice. These ends are now tucked under the strands of the standing part of the rope, as before, and after this has been done twice and the ends drawn taut, they are cut off, and the splice is hammered round with a hammer or a mallet.

Chinese Waterlift

The weight of water carried by this chain of cans is likely to astonish us. It is a small can that will hold only a pint of water, and a pint of water weighs a pound. If we are going to raise water to a height of 20 feet and place

our cans 1 foot apart, there will be a steady weight of 20 pounds for us to lift, and if larger cans are to be used, the load will be correspondingly greater. Of course, the belt can be operated by pulling down on the empty can side, but this is liable to be found a very tiresome job. The task will be simplified if we use a scheme that the Chinese often use for raising water. It is pictured in Fig. 139.

We shall have to erect a platform over the water at each side of the pulley. The shaft on which the pulley is mounted must extend about 6 inches beyond the lever at each side, and to either end pedals must be fastened. There are four such pedals for each side, which are arranged in the form of a cross. Take two pieces of wood, about 16 inches long and 2 inches wide. An inch to one side of the middle of each, cut a not 1 inch deep and as wide as the thickness of the wood. Put the two strips together, notch to notch (see Fig. 140) and nail them together. Then nail them fast to one of the projecting ends of the pulley shaft, making sure that the shaft lies in the crotch between the two longer arms of the cross, as shown in Fig. 141. Then a block of wood with a hole in it to receive the shaft is nailed fast to the posts. Fasten a similar cross of pedals on the other end of the shaft, but turn the cross around so that its arms are staggard with those of the first cross.

The platforms at each side of the pulley should be cut away so that the pedals will just clear them, and they should come at the normal level of the shaft. The platforms need not be anything very elaborate. In fact, all that is necessary is a pair of posts, E, Fig. 139, planted firmly in the bottom of the pond and projecting about 4 feet above the

level of the water. The platforms can then consist of a couple of shelves, F, supported on brackets on the posts, while a crosspiece, G, from one post to the other, will serve as a hand rail. Of course, a plank will have to be laid from the platform to the shore so that the boy who is to do the pumping can reach the pumping machine.

To work the apparatus, stand astride the pulley wheel and take hold of the hand rail to steady yourself. Then step first on a spoke or pedal on the right side of the pulley, then on a pedal on the left side, and so on. The wheel will turn quite easily under your weight. It will be a sort of stationary walking exercise, and it will take but a short walk to fill the cask. As the spokes are narrower and shorter than your shoe, and the platform fits very close to them, there will be no danger that your foot will follow the pedal down past the platform and slip into the water.

The Treadmill

This apparatus is something like an ordinary treadmill, which, by the way, makes another very good way of operating the " chain of pots," although it is a more elaborate and difficult machine to make. For the treadmill, we shall need five V-grooved pulleys, two belts of rope and a lot of barrel staves for the treads of our mill. We can just as well place our treadmill at the top of the bluff and connect it by rope belt with the water-raising machine.

For the frame of our treadmill, we shall have to have two posts 4 feet long and two 5½ feet long (Fig. 142). The shorter posts are to be set up at the rear of the machine, a little over 30 inches apart, or just enough for the

barrel stave treads to clear them. They should be connected by diagonal braces, as shown in Fig. 143, care being taken not to have the braces come so low as to interfere with the tread mechanism that is to be placed between

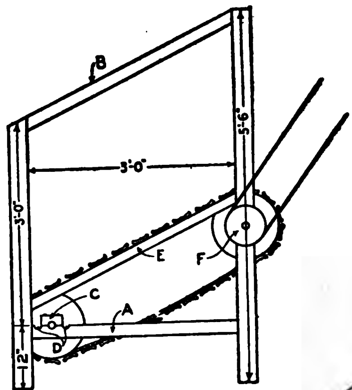


FIG-142

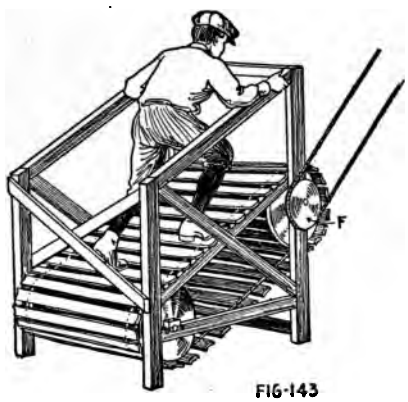


FIG-143

FIGS. 142 AND 143.—The treadmill

them later on. Three feet ahead of these posts, the longer ones are placed, and they are connected to each other by crosspieces at the top and the bottom. The front posts are fastened to the rear ones by means of a stout board, A, Fig. 142, at the bottom and a hand rail, B, at the top, while a

diagonal brace stiffens the structure. The pulleys for our treadmill must be about 1 foot in diameter and should be mounted on stout wooden axles. A couple of pieces 3 feet long, cut from a rake handle, will make excellent shafts. Two pulleys will have to be fastened on each shaft so that when one turns the other will have to turn as well, and they must be spaced about 28 inches apart, or 4 inches from each end of the shaft.

Two bearing blocks, C, are attached with screws to the boards, A, and then bearing holes are bored so that they lie half in the blocks and half in the board, as shown in Fig. 142. Half holes, D, are also cut in the board A, so that the bearing can be adjusted to tighten the tread belt. Holes are bored in the longer posts for the upper shaft 2½ feet above the ground.

After the shafts and pulleys have been set up in their bearings, a rope is stretched around each pair of front and rear pulleys and its ends are spliced together to make an endless belt. To these belts the barrel staves are fastened, leaving a space of about 2 inches between staves. The barrel staves are applied face upward. Holes are bored through the barrel staves near each end through which soft iron wire is passed and lashed around the rope belt and then drawn tight by twisting it with the pliers. Care must be taken not to have the V groove in the pulleys so deep that the wheels will tend to pry the treads off the belts.

To keep the tread belt from sagging too much between the pulleys, a couple of guides will have to be provided, one at each side of the treadmill. These guides may be wooden rails, E, secured to the posts so that the ends of the barrel

staves will rest on them. The guides had better be set out an inch or so from the posts by means of blocks of wood so that they will be sure to reach under the ends of the staves.

To use this treadmill, it is merely necessary to walk on the belt, using the hand rails at each side to steady yourself, and the belt will travel, turning the two pulley shafts. As our upper pulley shaft extends beyond the frame of the treadmill at one side, we can fasten our fifth pulley, F, to it. All the pulleys on this shaft must be very securely nailed fast, because this is the power shaft and will have to do all the real work.

An extra pulley must be secured to the shaft at the upper end of our chain of pots, and a belt should run from this pulley to the power pulley of the treadmill. The bearings of our treadmill must be well lubricated with tar or graphite, and some of the same lubricant must be applied to the guide strips, E, so that the treads will slide easily upon them.

The Bucket Dredge

We have settled on Briar Cove for our dock. Our survey showed us that the water is very shallow here, and the bottom is soft mud, but we are not going to let that stop us; we are going to build a dredge and excavate a harbor and a channel leading out to deep water. We can make the channel wind so that no stranger could make his way up to the dock without running aground.

First, we must build a scow to carry the dredge. After we are through with the dredge, we can remove it from the

scow and have a boat with which the pond can be navigated. The only drawback is that the scow will necessarily be rather clumsy. To make a good base for the dredge, it should be about 12 feet long and 3½ feet wide. A 14-foot scow would be even better, but anything less than 12 feet in length would hardly do.

Construction of the Scow

Take two boards 1 inch thick, 12 inches wide, and 12 feet long. Measure off 2 feet from each end of the board and draw the lines *AB*, in which *B* is on the center line of the board (Fig. 144).* Cut the boards off along these lines, and we have the side pieces, or "strakes" of the boat. The two strakes are set on edge, longer side up, and connected at each end and in the middle by means of boards C, D, E and F, 3 feet 6 inches long. The width of the boards and their position in the boat are given in Fig. 145. C and E will have to be made up of two or more boards. At E is where the derrick, or crane, is to be placed, and here the boards must be at least 1 inch thick and of hard wood.

Now turn the boat upside down and nail on the bottom (Fig. 146). The bottom may be made up of comparatively narrow boards, say 3 or 4 inches wide and 1 inch thick. The joints should not be closed up too tightly, because the wood will swell after the boat is in the water. If just the right clearance is allowed at the joints, the cracks will close when the wood swells and there will be

* For Figs. 144-150 see Frontispiece.

no leaks. But it is impossible to give directions here as to the amount of clearance, as this will depend upon the nature and dryness of the wood. Most boats require some caulking of the joints, and the chances are a hundred to one that this boat will leak like a sieve unless we pack the joints with some good packing material. The best filler is a strip of flannel coated with white lead. White lead may be bought at any paint store. Caulking strips should be laid between the bottom of the boat and the strakes. First the edges of the strakes should be given a good coat of white lead and then the flannel strips are laid on the painted edges and are themselves well painted with white lead before the bottom boards are nailed on. As each bottom board is nailed on, a strip of paint-soaked flannel is laid between it and the previously fastened board. If the boards are very dry, it is better not to have the joints fit too snugly, otherwise there will be no room for swelling when the boat takes to the water. After the bottom has been nailed on, the bow and stern boards are nailed fast and the hull of the dredge is completed, except for the keel. This is a strip of wood about 1 inch square which is nailed to the bottom of the boat along the center line.

Before adding anything more to the hull, it would be well to launch it. It will be found heavy enough as it is. In place of oar locks, a pair of thole-pins, G, Fig. 147, may be nailed to each side of the boat. As for oars, nothing very elaborate need be provided, because the dredge will probably be poled rather than rowed around the pond. A couple of broom handles or poles with shingles nailed to them will serve as makeshift oars. The thole pins will be

found useful as chocks for the anchor lines, and another pair of thole pins, H, should also be provided at the bow for the same purpose and also so that they can be used for sculling, if necessary.

The Dredge Derrick

We are now ready to go ahead with the dredge itself. For the tripod of the derrick, take three boards, each 6 inches wide and ¾ inch thick, two of them 7 feet long and the third 10 feet in length. Take the two shorter boards and fasten them together temporarily with a nail at one end. Spread the other two ends 3½ feet apart and fasten them to a base board, making a triangle as in Fig. 148. Be sure that the triangle is perfectly symmetrical, one leg being exactly as long as the other. Then saw off the corners that project below the base board. At the top of the triangle, cut the slot, I, Figs. 148 and 149, through both boards ¾ inch wide and 6 inches deep. First the vertical saw cuts are made, then the boards are knocked apart and the horizontal cuts are made clear through to the edge of the board. This done, the boards are brought together again and permanently nailed fast. The base board is now knocked off and the legs are made fast to the boat by nailing them to blocks, J, which in turn are nailed to the platform, E, 4½ feet from the stern. Just under the bow seat, C, a block of wood, K, should be nailed to the slanting bottom of the boat just to one side of the center line so that the third leg of the tripod can be nailed to it right on the center line. As this leg is to be canted at an angle of about 50 degrees, and the bottom of the boat is

also slanting at this point, the foot of the board will have to be cut off at a corresponding angle, but this does not have to be done with absolute accuracy. Fasten the board to the block with a single nail at first until the other end has been secured. At the upper end fit it into the slot I, cutting a notch, Z, Fig. 149, in it so that it will rest squarely on the bottom of the slot. The three legs should be firmly nailed together, but this is best done by using blocks through which nails can be driven both into the 7-foot legs and the 10-foot leg. Now return to the foot of the longest leg and nail it firmly to the block K.

The Derrick Boom

For the boom of the derrick, use two light boards of ¾-inch or even ½-inch stuff, 6 inches wide and 10 feet long. Find two small pulley wheels; the exact size doesn't matter very much. Place them between the two boards of the derrick boom near the outward end. Use a heavy nail or a bolt for the axle of each pulley and insert a space block between the boards to keep them from binding upon the pulleys (see Fig. 150, which shows the end of the boom with one of the boards broken away). At the foot of the boom, use a space board 12 inches long, and to strengthen the boom nail diagonal strips of wood across from one board to the other as shown in Fig. 151.

The Swivel Table

The boom is hinged to a swivel table made of two barrel heads nailed face to face so as to form a grooved edge. Lay the barrel heads so that the boards of one will lie at

right angles to those of the other. Get four low casters and fasten them to the under side of the swivel table, two in front and the other at the rear, spacing them equally. If casters are not to be had, use the so-called "domes of silence." A piece of tin should be tacked to the platform for the casters to run upon. The table is swiveled to the middle of the platform, E, by means of a bolt that has a nut screwed against each side of the platform.

The boom is now hinged to the swivel table with a pair of good stout barn-door hinges, as shown in Fig. 151. A rope is run around the swivel table in the grooved edge, and the two ends are carried back and fastened to cleats, as shown in Fig. 147. This rope is made fast to the swivel table by means of a staple right under the boom.

At the top of the tripod of the derrick, the longer leg projects out over the swivel table. Directly over the center of the table a pulley block is suspended. A rope runs over this pulley, and one end is attached to the boom about 7 feet from the swivel table, while the other end is made fast to a cleat. It is with this rope that the boom is raised or lowered to swing the bucket in toward or out from the boat.

Hoisting Drums

About 4½ feet above the swivel table, a brace, L, Figs. 147, 151 and 154, is nailed across the two shorter legs of the tripod and two pulley blocks are tied to this. They carry the ropes that pass over the pulleys in the end of the boom, and run down to the bucket of the dredge. These ropes are wound up on the drums, M, which are made as shown in Figs. 153 and 154. Take six sticks of wood each

20 inches long, and in the middle of each bore a hole just large enough to fit freely upon a rake handle. The sticks will have to be 2 inches wide and ¾ inch thick. In each stick bore two holes just 3 inches at either side of the middle. Then with a draw knife shape the ends of the sticks to form neat handles. The holes above referred to will have to be just large enough to receive with a driving fit a pair of round rods. Chair rungs would make ideal rods, if these are to be had. At any rate, the rods must be about ¾ inch thick and 12 inches long. Now take three of the sticks and mount them upon the rake handle; then spread them out into a six-pointed star, with the points of the star all equally distant from each other. Then nail the sticks securely together. Do the same with the other three sticks, and this gives us the two heads of our winch, or hoisting drum. These heads are now connected by means of the rods which are driven firmly into place. If the two heads are turned until the innermost stick of one head faces the outermost stick of the other, the rods will all fit flush with no projecting ends. A long brad, or thin wire nail, driven through the stick into each rod will make the drum doubly strong and keep it from working loose as the wood shrinks under the influence of the weather.

Two drums will have to be made, one for the rope that carries the bucket with its jaws open and the other with the jaws closed. The second drum is made just like the first. The two winches are now mounted on the rake handle, and the latter is made fast to legs of the tripod about 2 feet above the swivel table. A crosspiece, N, Figs. 151 and 154, is nailed to the tripod below the drums just far

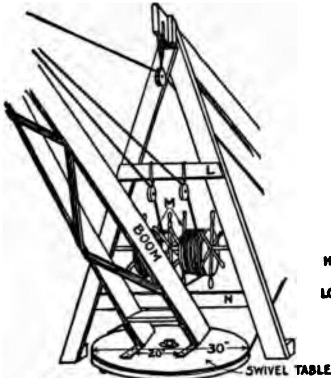


FIG-151

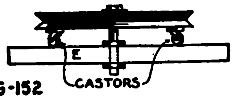


FIG-152

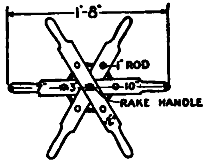


FIG-153

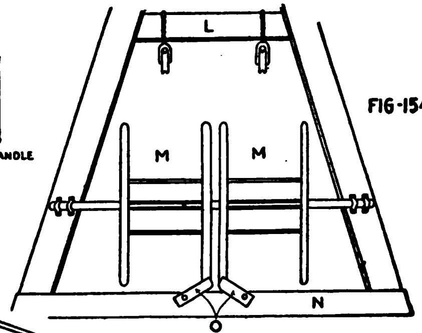


FIG-154

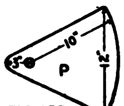


FIG-155

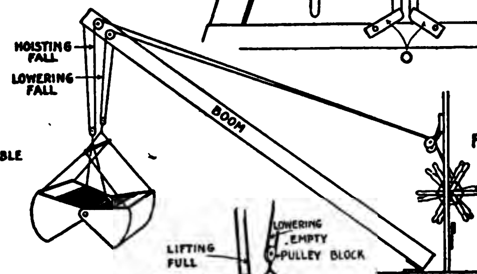


FIG-157

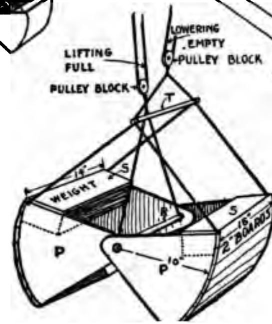


FIG-156

enough to clear the spokes or handles, and on this crosspiece there are two buttons, O, which may be turned up to engage the spokes or handles of the drums when they have been wound up as far as desired.

The Clamshell Bucket

Now let us turn to the bucket of our dredge. Cut out four sectors, P, of the size and shape indicated in Fig. 155. Use a piece of tough rod, R, Fig. 156, such as a rake handle, for the jaws of the bucket to swing upon, and bore a hole in each sector to fit the rod. Two of the sectors are to turn on the rod, and these should have a slightly larger hole than the others which are to be nailed to the rod. The bucket should be about 15 inches wide, but one side will have to lap over the other, and as the sectors will be made of 1-inch stuff, it would be best to make one side 14 inches wide and the other 16, and so, for the rounded sides of the bucket, two sets of boards will have to be cut out, one set 14 inches long and the other 16. These boards should be of ½-inch stuff and about 2 inches wide. Where the jaws come together, bevel off the boards so that they will form sharp cutting edges and sheath these edges with tin to keep them from wearing.

Each jaw of the bucket will have to be weighted, to keep the bucket from floating, and also to help it dig into the mud when dredging. Build in a box, S, about 6 inches wide and 3 inches deep in each jaw, as shown in the drawing. Fill each box with small stones or pebbles and then nail on the lid. Hinge the two jaws together on the rod, R, nailing the outer sectors to the rod. Run a rope from

each end of the rod about 2 feet long and make fast to the hoisting pulley. From the four outer corners of the bucket jaws, run ropes to a spreader rod, T, and connect this in turn by means of a pair of short lengths of rope to the lowering pulley. Fig. 157 shows how the ropes are attached to the boom, pass through the hoisting and lowering pulleys and then over the pulleys in the boom and the pulleys in the tripod to the winches.

This completes our dredge, but before we use it, we must have something in which to put the excavated material. Of course, if the dredge is working near shore, the mud excavated can be dumped upon land. But for most work, a mud scow will be required. Now an ordinary scow will hardly be very serviceable, because, after it has been loaded, it will be no small task to unload it again. The only thing to do is to build a dumping scow.

The Dumping Scow

For the side pieces or strakes of the dumping scow, cut out two pieces exactly like those of the dredge (see Fig. 144). In addition to these, two more boards will be required, 12 feet long and 8 inches wide, so as to make the sides of the scow deeper and increase its carrying capacity. Two bulkheads, U, will have to be sawed out of 1-inch board to the dimensions given in Fig. 158. Instead of trying to get a single board 18 inches wide, it will be much better to make the bulkheads each out of two boards 12 and 6 inches respectively. The two boards are fastened together by means of battens. Two boards, V, Fig. 159, are cut out on the same angle as the bulkhead U, but they are only 6 inches

wide and hence only 3 feet 8 inches long at the top. These boards are used to connect the two 12-inch strakes at the middle of the boat.

The two bulkheads are nailed in place 2 fcet each side of the middle, or 4 feet from each end of the booat, as indicated in Fig. 160. Then the upper strakes are nailed to

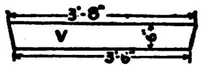


FIG-159

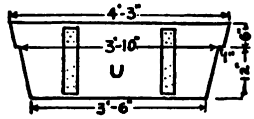


FIG-158

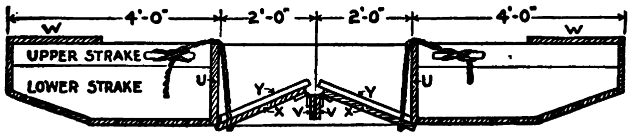


FIG-160

FIGS. 158 TO 160.—The dumping scow

the bulkheads with their lower edges overlapping the lower strakes about 2 inches. These overlapping edges are nailed together securely throughout the length of the boat. At each end, the strakes are connected by means of the boards, W, which will serve as seats and also to reinforce the boat. The boat is now turned upside down, and the end pieces and bottom are nailed on, in the same way as in the construction of the dredge, with the exception that between the bulkheads, U, an open well is left. The middle

of this well is spanned by the two cross-pieces, V, to which are hinged two doors, X, that close the well. The doors will have to measure 3′–6″ by 2′–3″ and will have to be fastened with strong barn-door hinges. Ropes are attached to the free ends of the doors and passing up over the bulkheads are fastened to cleats to hold the doors closed. In order to close the gap between the doors and the side of the boat, strips of wood, Y, should be nailed to the strakes forming a frame against which the door is closed. Of course, no attempt is made to have the mud well, or hopper, watertight. When the doors are opened to dump out the mud, water will take its place. Naturally, it will not sink the scow, to let in this water, because the water is not as heavy as the mud whose place it will take. The fore and aft sections of the boat each side of the mud hoppers will furnish enough buoyancy to support all the mud that can be carried in hoppers. In fact, the hopper might be extended by building up its walls 6 inches higher, if it be desired to increase the capacity of the boat.

Dredging a Channel into Briar Cove

Now we are ready to do some real dredging. First we must stake out the channel and basin that we wish to excavate. Then the dredge is anchored fast in position to eat into the mud. Anchor ropes should run out from the chocks G and H of the dredge. Long ropes should be used, fastened to heavy stones so that it will not be necessary to weigh anchor whenever the boat is to be moved, but by slackening up on some and taking up on others the dredge may be manœuvred to any desired position in a very

short time. The scow is made fast to the dredge where it will be handy. The boom is lowered until the bucket conveniently clears the bow of the dredge, then one of the winches, M, which carries the hoisting fall is released and given a complete turn so that the weight of the bucket will come on the lowering fall and the jaws of the bucket will be opened wide. Then, with jaws open, the two falls are rapidly paid out, letting the bucket drop into the mud. That done, the lowering fall is slackened off and the hoisting fall is wound up. This will cause the two jaws to swing together, biting into the mud. The bucket is raised by means of the hoisting fall until it is at a convenient height to be swung out over the dumping scow, when the button, O, is turned to hold the winch fast. The next operation is to turn the swivel table until the bucket hangs directly over the hopper of the mud-scow. Then, by hauling in on the lowering fall and letting out on the hoisting fall, the jaws of the bucket will be opened and the load dumped into the hopper. Thus the work will proceed, lowering the boom when necessary to reach farther out from the dredge, and swinging it to one side or the other to reach new ground. When the scow has been loaded sufficiently, it is moved out to deep water and dumped by slackening off on the ropes that hold the doors of the hopper.

CHAPTER VII

WHARVES AND BRIDGES

FOUR-HANDLED RAM. THE PIKE POLE. CONSTRUCTION OF A PILE DRIVER. THE CONCRETE RAM. THE TOWER OF THE PILE DRIVER. CONSTRUCTION OF A WHARF. CONSTRUCTION OF A BRIDGE. HOW THE SWING SPAN IS MADE. THE LIFT SPAN.

Our channel into Briar Cove has been excavated and also a basin near shore in which we are to place our wharf. To build this wharf we shall have to have some means of driving piles.

Four-Handled Ram

For ordinary light work a large four-handled mallet or ram is sometimes used. The ram can be made out of a block of wood and a couple of rake handles. The larger the block of wood the better. A piece sawed off a 12 by 12 beam would make an ideal ram head. The piece should be 8 or 10 inches long. The best results will be had by using the end of the piece as the hammer face; that is, the pounding will be done on the end of the wood fibers. To keep the wood from splitting, take a piece of band iron, such as is used on packing boxes, and draw it tightly around the block near the face, fastening it at frequent intervals with short nails. Do not use tacks for this purpose, as is some-

times done on boxes, because they will not provide sufficient security. The rake handles should be attached to the ram head at the top as shown in Fig. 161. They should be secured down to the block not only by nailing them fast but also by fastening straps of band iron around them. The nails should be driven in on a slant so that they will hold firmly.

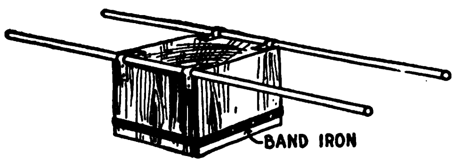


FIG. 161.—The four-handled ram

THE PIKE POLE

This ram is operated by two boys standing on opposite sides of the pile that is to be driven, each holding a pair of handles. The pile must be guided by another boy, or preferably by two boys, each provided with a pike pole. The pike pole is made of a rake handle with a tenpenny nail A (Fig. 162) driven into one end and a second tenpenny nail, B, driven into the side of the stick. There should be a ferrule on the end of the stick to keep it from splitting when the nail is driven in. The head of the nail should be filed off, leaving a sharp point. (A ferrule, by the way, can be bought at any hardware store for a few cents.) Care should be taken in driving the second nail through the side of the rake handle. It will be best to bore a small hole through the stick and then drive the nail through the hole.

In the lumberman's pike pole, the part which corresponds to this nail is curved to form a hook. Of course, we could curve our nail in the same way, but, as we have nothing to keep it from turning, the chances are that it would twist around, so that the hook would curve in the opposite direction, when, of course, it would be useless for our purposes. We must depend instead on a straight sharp-pointed nail.

The pile may be steadied by pushing the point, A, of the pike pole against it or by pulling it back with the nail, B. Two boys on opposite sides of the pile can hold the pile very steadily while two other boys are pounding it down with the ram.

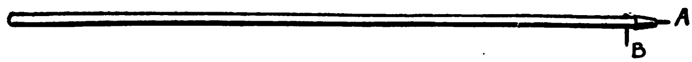


Fig. 162.—The pike pole

This type of pile driver will be most useful in swampy places where a board or two may be laid down to provide a good footing for the workers. When the piles are to be driven in open water and the water is too deep for the workers to wade in it comfortably, boats must be used. But this is a bothersome thing to do, because boats have a way of slipping out from under a fellow's feet unless they are firmly anchored. Another disadvantage of the hand-operated ram is the fact that it cannot be used efficiently when the piles are sticking high up out of the water or mud. If the top of the pile is more than waist high, it will be very awkward to pound it with the ram, and so this type of pile driver will hardly do for driving piles deep into

the mud. Still another disadvantage is that it takes some practice for two boys to swing the ram with the proper team work.

After all, we had better build a real pile driver something like the ones that are used in regular engineering work. This may seem like a difficult job, particularly as we cannot undertake to build a steam engine to work the pile driver. However, we can turn again to army engineers for a suggestion in this emergency. Army engineers have to do a great deal of bridge building under trying conditions, and they are frequently hampered by the lack of tools, but they are not prevented from building a trestle or pile bridge, because they have no pile driver handy. They rig up a substitute apparatus and use man power to lift the ram of the pile driver. The ram is lifted up to the top of the guide way by means of a cable that passes over a pulley. A dozen or more hand ropes are attached to the cable so that it can be hauled up by as many men. With this as a clue, we can proceed with the construction of an emergency pile driver, ourselves.

Construction of a Pile Driver

As most of our work is to be done in the water, we had better build our pile driver on a scow. If necessary, we can dismantle the derrick of our dredge and use the hull of the boat for our pile driver. This will save us the trouble of building another scow, and the pile driver mechanism does not have to disfigure the scow in the least. When we are through with it, the structure can readily be taken down,

and the dredging mechanism can be restored, or else the boat can be used for other purposes.

The Concrete Ram

Our first work had better be on the ram. This is to be made of concrete, as that will give us a good heavy block which can readily be constructed by any boy. Our concrete block should measure 10 inches deep, 6 inches thick, and 10 inches long. There must be grooves in opposite sides to fit the rail of the guide-way, and in the top of the block there must be a large eye, to which the hoisting cable may be attached.

We shall have to make a mold for the ram, which should be a box with inside measurements the same as that of the ram (see Fig. 163). The sides of the box should be very lightly nailed, leaving the heads of the nails projecting so that they can be readily withdrawn after the casting has been made. As concrete hardens it expands and grips the mold so tightly that it cannot be taken out without taking the mold apart. To form the grooves in the block, sticks of wood, A (Fig. 163), known as rabbets, are nailed to the inside of the end boards of the mold. This is, of course, done before the box is nailed up. The rabbets should project at least 1¼ inches from the face of the board and should be 1 inch thick. For the eye in the top of the block, maybe we can find a large screw-eye somewhere in the junk pile. Failing this, we can use a loop of heavy wire instead. The screw-eye may be held in place in the open top of the mold, as shown at B, between a pair of battens, C.

The concrete for this block is prepared by mixing up one part of Portland cement with two parts of sand and three parts of broken stone. In making up a batch of concrete, the best plan is to put the cement and sand together dry, turning the mixture over with a trowel until it is thoroughly mixed. This may be done in a pail or a box. Then in another box the stone is placed. Small broken stone with jagged edges makes the best material, but coarse gravel can be used as well. For this work, the stone should not be much more than an inch in diameter. The stone is

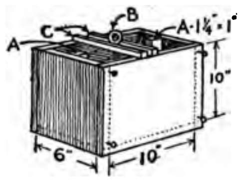


FIG. 163.—Mold for the concrete ram

wetted down and then water is poured into the sand and cement mixture to form a creamy paste. This is now poured over the stone, and the mixture is turned over and over with a trowel or garden fork, until every stone is completely coated with the cement and sand. The greatest care must be taken to get a thorough mixture, because on that will depend the strength of the block, and the ram must be very strong to stand the pounding to which it is to be subjected. After the concrete has been thoroughly mixed, it may be poured into the mold and then put aside to set. Be sure to have plenty of water in the mixture, because unless the cement has enough water to give it a milky consistency at the top of the mold, it will not give the

best results. It will be well to let the mold stand for a full day before taking it apart, and then the ram should not be used for two or three days, in order that it may have a chance to become thoroughly hardened before it sees service.

The Tower of the Pile Driver

While the concrete is setting, we can proceed with construction of the pile-driver tower. For this we shall need a couple of wooden rails 12 feet long, 2½ inches wide, and ¾ inch thick. These are to fit into the slots in the sides of the ram. Take a board 11 feet long and 10 inches wide, and say ¾ inch thick. Saw this in two lengthwise on a slant, so that you will have two strips 1 inch wide at one end and 9 inches wide at the other. These are the side frames of the tower. The rails are nailed to the straight edge of these pieces, so that they extend a foot beyond the bottom or broad end of the side frames and the latter are connected by braces far enough apart to let the ram slide freely between the rails. Fig. 164 shows the construction. The rails may be seen at A, the side frames at B, and the braces at C, while the ram is shown at D. The braces cannot be placed near the top of the tower, because they will interfere with the ram, but at the very top of the tower above the point where the ram is to slide, a brace may be nailed across from rail to rail. A grooved pulley wheel, E, should be mounted at the top of the tower. The wheel must be about 4 inches in diameter, and it may be mounted on a round stick of hard wood not less than ¾ inch in diameter, which is nailed to the tower frames A.

The tower is attached to the scow by means of a couple of beams, F, which should be about 2 inches square and 5 feet long. These beams are nailed to the deck of the boat, letting the rails of the tower project about 4 inches beyond the stern of the boat. To make that tower per-

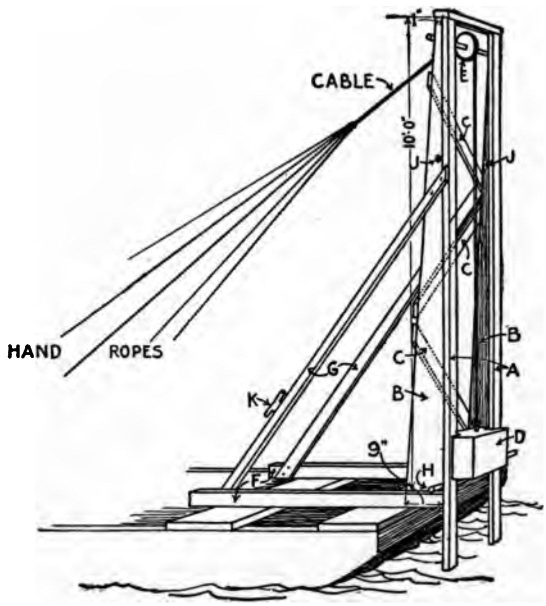


FIG. 164.—The pile driver mounted on the scow

fectly steady, two diagonal braces are put in, as shown at G. The side frames of the tower will rest on the deck of the boat, but the rails A will project down to the surface of the water.

By the time the tower is finished, the ram will be sufficiently hardened. We can then proceed to mount it in the

tower. A cable is passed over the wheel at the top of the tower and at one end it is knotted fast to the eye in the ram, while at the other a number of hand ropes are attached to it. The ram will weigh about 50 pounds, and if five hand ropes are used, each boy will have to lift only 10 pounds of weight, provided each boy is lifting his share of the weight. The ram is introduced into the tower from the bottom, and when not in service it may rest on a stick of wood, H, that is passed through holes in the side frames of the tower near the deck line. Two more holes, J, are bored through the frames close to the rails about 6 feet above the deck, so that a stick may be introduced here to support the ram while a pile is being adjusted under it to the proper position between the rails of the pile driver. There should also be a cleat, K, on one of the braces, G, to which the hoisting cable may be secured when the ram is not working.

Our pile driver scow must be provided with four long anchor lines running out from each corner of the scow, so that it can be made fast in any desired position by taking in on this or that anchor line and letting out on the opposite one. In using a pile driver, one boy must hold the pile in place between the rails of the tower by means of a pike pole, while a gang of four or five boys haul the ram to the top of the tower and then on a given signal release it. The foreman of the gang shouts to the boys "Heave ho!" as they haul the ram up, and shouts "Drop!" as the signal to let go their ropes. The hand ropes should be long enough for each boy to fasten his rope to his belt. At the word "drop" he lets go the rope, instead of letting it slide through his hands, and on the instant that the ram strikes,

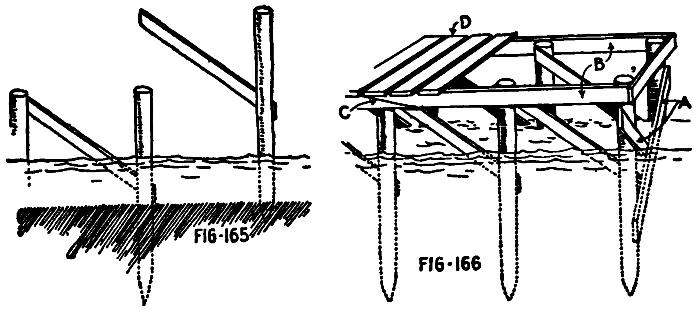
he takes in the slack and hauls the ram up again. With a little practice, a team of boys can learn to operate the pile driver with a steady rhythm that will produce excellent results.

Construction of a Wharf

Our wharf should extend far enough into the water to let a boat be moored alongside. We had better make it at least 12, and preferably 16, feet long, and it should be at least a foot above the high-water mark of the pond. The wharf ought to be from 30 to 36 inches wide, and this will call for 2 rows of piles about 30 inches apart. The length of the piles will depend upon the nature of the bottom. The piles should be spaced about 4 feet apart along the length of the wharf. Each pile should be connected to the one behind by a diagonal brace. The brace is nailed to the pile before it is driven all the way down, as indicated in Fig. 165, and then after it has been driven home the opposite end of the brace is fastened to the top of the next pile to the rear. To stiffen the wharf sidewise, a pair of diagonal braces connect the outermost piles, as shown at A, Fig. 166. The lower ends of these diagonal braces are also nailed fast, before the piles are driven all the way home. After all the piles have been driven, stringers, B (Fig. 166), are nailed to the sides of the piles. These stringers may be 4 inches wide and 1 inch thick. Join the stringers where they are nailed to a pile, cutting the ends off on a slant, as shown at C, so that they can be nailed together as well as to the pile. The tops of the piles should then be sawed off on a level with the top of the stringers.

The flooring, D, of the wharf can now be nailed down to the stringers. The floor boards should be spaced an inch apart, so as to let rain water, or any water that may splash up over the wharf, drain through freely. After the floor boards have been nailed to the stringers, they may be cut off to an even length by running a string line from one end of the wharf to the other and sawing along this line.

For the piles of the wharf, we shall have to use any-



FIGS. 165 AND 166.—The construction of the wharf

thing we can get hold of, but if we can have our choice, we should use sticks at least 3, and preferably 4, inches in diameter. The end of the pile that goes into the ground should be the top, or smaller end of the stick, and ought to be cut to a point.

CONSTRUCTION OF A BRIDGE

A bridge can be constructed in exactly the same way as the wharf, although it will be best to raise the deck of the bridge at least 30 inches above the water so that a boat can go under it, and at least one of the spans should be

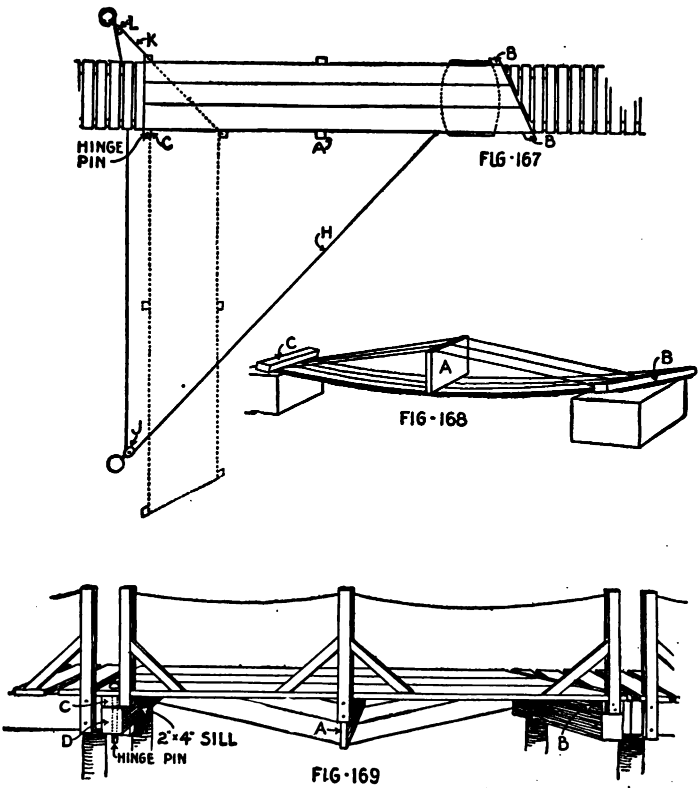
6 feet long so as to leave room for a boat to go through. A bridge ought to have a hand rail at one side or both. The rail should be 30 inches above the deck of the bridge, and it may consist either of a rope or of a strip of wood attached to light posts. Such a bridge as this might very well be thrown across the Otter River where it enters the pond. However, it will block the passage up the river to anything like a pile driver or a dredge or to a scow fitted with any sort of superstructure, and as we shall probably find it very necessary to bring the pile driver upstream, later on, it will be advisable to put a draw in our bridge.

Suppose we take a span of 10 feet for the draw. The approaches of the bridge can be built in the usual way on piles, leaving a 10-foot gap between. There are several ways of operating the draw span. One way is to hinge one end to the approach and carry the other end on a scow. Another way is to lift the span up when boats are to pass.

How the Swing Span is Made

The swing span will have to be constructed very differently from the lift span. However, both forms of span will have to be trussed to keep them from sagging, particularly as we are going to make the construction very light, so as to make it easy to handle the draw. The swing span must be square at the hinged end and should be cut at a slant at the free end, so that it will clear the fixed part of the bridge when it is opened. Fig. 167 shows the construction. It is a plan view of the bridge and shows by dotted lines the position of the bridge when open. It is made of three boards, each running the full length of the span, and

connected at the middle and near each end by means of cross beams. The beam at the middle is a board set up



FIGS. 167 TO 169.—The construction of the swing span

on edge. It should be at least a foot deep, and three wires, one under each floor board, are stretched tightly from one end to the other on the under side as shown in Fig. 168. The wires should be drawn tightly enough to bow up the

draw span somewhat at the middle. This is best done by laying the span bottom upwards with the ends resting on a couple of trestles, or boxes. The middle of the span will then sag a little or can easily be made to do so with a little pressure. The wires are then made fast to nails driven into the wood and clinched on the opposite sides so that they will not pull out. The nails should be driven in on a slant so as to take the pull of the wire better. Galvanized iron fence wire should be used of size No. 10. Where the wires cross the beam A at the middle of the span, they should be fastened to it by means of heavy staples. A span thus constructed cannot sag, because the middle of it will be held up by the pull of the wires on this beam. At the point where the span is to be hinged to the fixed part of the bridge. Nail a 2 by 4-inch sill across the two end piles for the end beam of the span to rest upon (see Fig. 169). The height of this sill, D, should, of course, be adjusted so as to bring the floor of the swing span on a level with the floor of the fixed part of the bridge. At the upstream corner of the span, a hole should be bored through the floor beam, C, and through the sill, D; in fact, the hole in the sill had better be bored before it is attached to the piles, as it will be found more convenient to work the bit brace where it is not obstructed by the structure of the bridge. The size of the hole will depend upon whether we can obtain an iron bolt for the hinge pin or must use a wooden hinge pin. A half-inch iron bolt will be plenty strong enough, but if a bolt is not to be had, the hole must be an inch in diameter to receive a wooden pin which can be cut from a stick

of hard wood, such as a rake handle. It should be fastened into the sill by driving a nail through it.

The fixed end of the bridge, at the opposite end of the span, should also be provided with a sill, E, on which the end of the span can rest, and, as explained above, this must be set on a slant so as not to interfere with the opening of the draw. This end of the span is to be supported on a float when the span is swung open. As there will not be very much weight on the float, it can be constructed out of a box, the joints of which are made watertight by caulking them with felt soaked in white lead paint. A

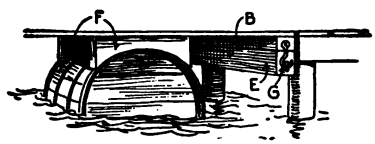


FIG. 170.—Float for the swing span

watertight barrel or cask would make an ideal float. The span must be supported on the float slightly above the level of the sill, so that it will swing freely when the span is opened. If a barrel or cask is used, supports, F, must be cut out to fit the rounded surface of the barrel, as shown in Fig. 170. When the span is closed, it may be held down on the sill by a hook and eye, G, at each side. To swing the span open, a rope H (Fig. 167), is attached near the outer end, which passes through a pulley, J, fixed to a post 6 or 8 feet upstream, and runs back to the fixed part of the bridge near the hinge. By pulling on this rope, the draw may readily be opened, while on releasing the rope, the current will swing the bridge back to closed position.

If the current is not strong enough, another rope, K, should be fastened to the outer end of the span and passed around a pulley, L, attached to a post at the downstream side of the bridge. Of course, the draw span should be fitted with a hand rail at each side, of the same type used on the fixed part of the bridge.

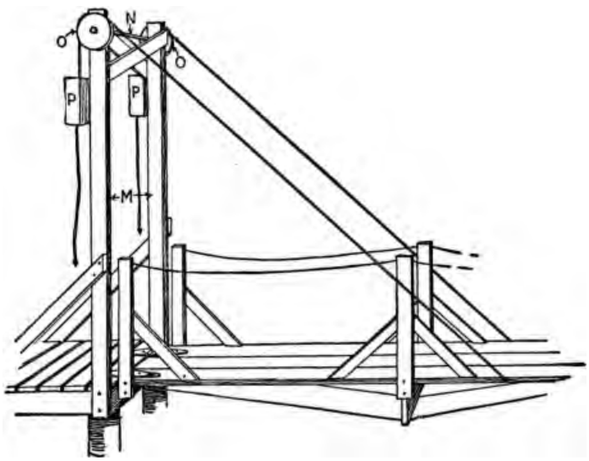


FIG. 171.—The lift span

THE LIFT SPAN

The construction of the lift span is just the same as that of the swing span, except that both ends are square. The span is fastened to the fixed part of the bridge by means of a couple of good-sized strap hinges. To the fixed part of the bridge a couple of uprights, M, 8 feet high, are erected and made fast by diagonal braces, as shown in Fig. 171. These uprights should be connected at the top by

means of diagonal braces to keep them from swaying from side to side. A wooden shaft, N, should be mounted in holes bored through the upper end of the uprights. The shaft must be long enough to extend beyond the uprights and must carry at each end a grooved pulley wheel, O. The shaft ought to be about 1 inch in diameter. Ropes tied to the draw span, 8 feet from the hinges, are passed over these pulley wheels and are secured to counterweights, P. The counterweights may be bags or small wooden boxes filled with sand. Enough sand should be put in the counterweights to take most of the weight of the span, but not all of it. The span can then be raised by pulling down on the counterweights, or it can be lowered by lifting them. By taking a turn of the counterweight rope about a pin or cleat projecting from each upright, the span may be held in raised position. It should never be raised quite vertically, because this is unnecessary, and if raised far enough to lean back against the uprights, it will not swing down again when the counterweights are lifted. The hand rails of the lift span should be set in far enough to come between the uprights when the draw is opened.

CHAPTER VIII

WATER POWER

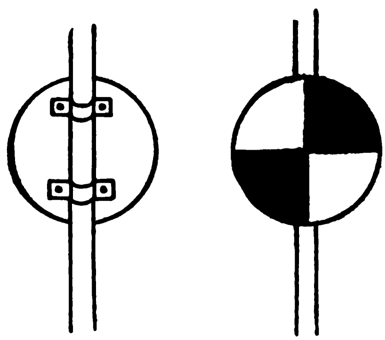
CRIBWORK DAM. THE PILE DAM. THE OVERSHOT WHEEL. THE SAWMILL WHEEL. THE BOAT ELEVATOR.

If we turn back to the map of our pond and river on page 123, we shall see that just a little above the point where the stream opens into the pond there are rapids which bar navigation. Beyond the rapids there is plenty of deep water in which a boat can be floated, and so here we have a call for some engineering work, which will enable us to overcome this obstruction. The ordinary method would be to dig a canal around the rapids and put in a lock to raise the boat from one level to the other. But the construction of a lock is not as simple as we might wish, particularly if the lift has to be a considerable one. Instead of building a lock, then, suppose we construct a boat elevator.

While we are about it, we may as well throw a dam across the river just below the rapids, so as to raise the water to a navigable depth over it. Then we can use the power of the water to run a water wheel. Of course we cannot attempt to build a dam of masonry or cement. That would be too expensive, but we can build a log dam if we can get the lumber.

First we must find out how much higher the water above the rapids is than that below. We must set up our

plane table in the stream above the rapids, leveling it very carefully. Then the rodman must set up his rod just below the rapids. The rod may consist of a pole with a target mounted to slide on it. The target is a disk of wood about 6 inches in diameter with two straps of tin or iron nailed to it and looped to fit the pole, as shown in Fig. 172. The face of the target should be laid off in quarters and painted



FIGS. 172 AND 173.—Target for the surveyor's rod

black and white, as shown in Fig. 173. The alidade is trained on the rod and the target is moved up until its center is in line with the cross-hairs of the alidade. Then the height of the alidade above water is subtracted from the height of the target above water, and the difference gives us the measure we are after. Suppose it amounts to two feet; then we shall have to make our dam at least three feet high to give us a safe navigable depth over the shallows of the rapids.

CRIBWORK DAM

The early settlers of this country used to build dams of cribwork, which were of very simple construction and a design that we can very well copy. Figs. 174 and 175 show how the cribwork is built up in the form of a triangular

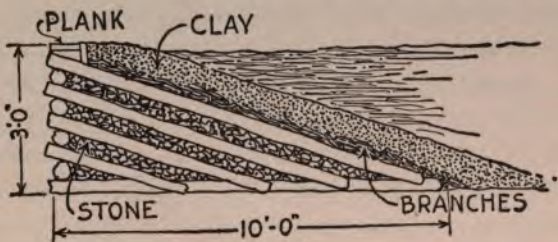


FIG. 174

FIG. 175

FIGS. 174 AND 175.—Section and front view of the cribwork dam

pile. The logs do not need to be notched together, but each one is spiked to the logs it rests upon. The inclined logs are placed about 3 feet apart, and the slope of the dam is upon the upstream side, of course. On this sloping face planks are laid; but as this is rather an expensive material for boys to handle, a better plan is to fill the cribwork with stone and gravel and then lay upon this a facing of branches on which may be laid a thick bedding of clay. At the crest

of the dam a couple of planks should be nailed, to take the wear of the water running over the top, and they should dip down toward the center of the dam so that the main current will be in the middle and not near the shore ends of the dam where it might wash away the banks. The greatest care will have to be taken to put down a thick layer of clay all over the sloping face of the dam and particularly where it joins the bank so as to hold the water in. When the clay is first deposited, it will be filtered through the mass of branches and stones, but gradually it will fill up and choke the flow of wâter. Of course the clay cannot stand the wash of running water, and to keep the water from getting under the planks at the crest of the dam another plank should be set upon edge behind them as shown in Fig. 174. Tamp the clay tightly against this plank.

The Pile Dam

A cribwork dam could be made much higher than three feet, but it requires a lot of lumber, and we shall find it more economical to build one of piles. Suppose we make one five feet high; that is, five feet above the level of the water below the rapids. That will give a good head of water for power purposes. First drive a row of piles across the stream, projecting 5 feet above the surface of the water. This will tax our pile driver to the very limit because the piles should be imbedded at least 2 feet into the bed of the river. The piles should be about 3 feet apart and should be from 4 to 6 inches in diameter. Another row of piles should be driven on the downstream side, about 3 feet from the first row. These will have to be driven far into the bed

of the river, as they are to form the toe of the dam. They need to project only a foot above water level. Diagonal braces must be extended from them to the longer piles at the top of the dam. At the crest of the dam, a couple of boards should be nailed on the upstream side so as to form a curb at least 20″ deep. As in the cribwork dam, the curb must dip toward the center so as to keep the current away from the banks. At the shore ends of the dam, the curb must be buried deep into the bank, and here sheet piles or boards should be driven endwise into the ground. By cutting the bottom of the sheet pile on a slant, it may be made to crowd into the bank (see Fig. 176). It must be thickly bedded in clay, particularly on the upstream side.

This work is done while the water runs freely between the piles. Before we start to put in the body of the dam, we must set in the gates. There should be a couple of these, one near each shore where they can be reached readily. The gates are made by nailing a couple of broad strips, A, Fig. 176, to opposite sides of the lower planks of the curb between and close to two of the piles, letting them extend 15 inches above the crest of the dam. The upper plank of the curb is then sawed through close to the piles and forms a gate, B, which may slide between these guides A. It may be held in raised position by resting on pins, C, which are passed through holes, D, bored through the guides. Boards, E, should be nailed to the top of the curb to furnish foot-paths leading to the gates.

The next step is to deposit a lot of sticks and branches into the water, letting the current sweep them against the piles. These branches will form a tangle that will dam up

the water to a certain extent. On this pile of sticks and branches loads of stone must be dumped to mat the mass and hold it down. Over the stones should be laid a layer of sand to fill up the chinks, and finally over the sand clay must be laid to form a tight bed through which the water cannot penetrate. Altogether, the slope of the material back of the dam must be a very gradual one so that the

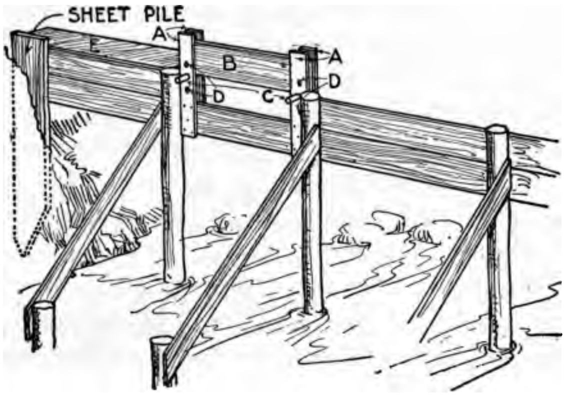


FIG. 176.—The pile dam

pressure of the water will tend to hold it down rather than to push it forward against the piles.

In getting this large amount of material in place back of the dam, good use will be found for the cableway described in Chapter V. The stone, sand and clay can be carried out over the dam and deposited by means of the dumping skip, without any trouble. The clay can be picked up from the banks at the eastern end of the pond, with the clamshell bucket dredge, and placed in the mud scow, from which it can be loaded into the skip of the cableway and

transferred to the desired place in the dam. The clay blanket must be built up to the level of the gate openings and elsewhere should come all the way up to the top of the curb.

THE OVERSHOT WHEEL

Now that we have built a dam, we may busy ourselves with the task of utilizing the power of water that flows over it. A good waterwheel is not a very easy thing to construct, but a crude one may be built without any very great difficulty. With a dam 5 feet high, the best wheel will be

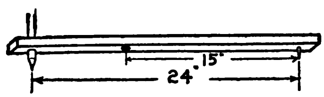
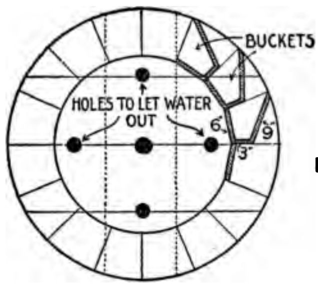


FIG. 177.—Compass for laying out the water wheel

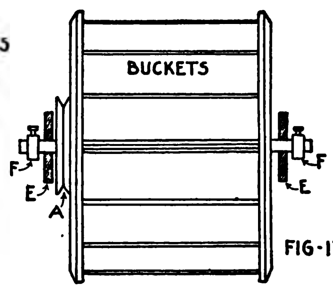
one of the overshot type. We shall have to build a wheel about 4 feet in diameter and 30 inches broad. First we must make two disks 4 feet in diameter for the sides of the wheel. Take four boards each a foot wide, or five boards if 12" lumber is not to be had, and nail them together securely by means of another board laid at right angles to them. Out of this set of boards the disks must be cut, to do which we shall need a compass that will draw a 4-foot circle. Take a strip of wood 1 inch square and a little over 2 feet long (see Fig. 177). Drive a nail through it at one end for the point of the compass, and bore a hole through it near the other end just large enough to receive a pencil. This hole should be exactly 2 feet from the point of the compass. A more satisfactory compass point can be

made of a wood screw driven through the strip with its projecting point sharpened by means of a file. The woodscrew is not liable to work loose in the compass as a nail would.

Setting the point of the compass at the center of the boards, a pencil is stuck through the hole on the opposite end of the compass, and a circle is drawn which is 4 feet in diameter; then with a compass-saw the disk is sawed



FIG·178



FIG·179

FIGS. 178 AND 179.—The overshot wheel

out. A second set of boards may now be fastened together out of which the second disk may be cut. On the inner face of each disk a second circle must be drawn just 30 inches in diameter, which means that a second pencil hole must be bored in our compass exactly 15 inches from the point. This circle must now be divided off into 16 parts, each of which will be very nearly 6 inches long (see Fig. 178), and radial lines must be drawn from these points to the edge of the disk. At each of these points a brad or headless nail should be driven into the wood, leaving the head projecting. These brads will form stops against

which the buckets of the wheel are to bear and will make it easier to set the buckets in proper position. Before these nails are driven, however, we must bore holes in the disks at the center for the shaft of the wheel. The disks should be laid face to face and the holes bored through both of them at one setting, so that they will surely be in alignment. The shaft will have to be of wood about 2 inches in diameter, and 40 inches long, and the holes should be large enough to run freely on the shaft. If an iron shaft is to be had, so much the better. A piece of gas pipe 1 inch in diameter will make an excellent shaft, in which case, of course, the holes in the disks need be but a shade more than 1 inch in diameter.

The two disks are now mounted on the shaft so that they will lie in proper relation one to the other, and we may begin to build up the buckets between them. The back of each bucket consists of a board 6 inches wide and 28 inches long, while the bottom board is 3 inches wide and the front of the bucket a 9-inch board. The 6-inch boards are fastened in place by nails driven from the outside of the disks, and it will assist a great deal in finding the right place for the nails if a 30-inch circle is drawn on the outside of the disks as well as the inside. Of course each 6-inch board as it is fastened in place will lie at an angle with the board next to it, and its edge should be bevelled a trifle so as to make a close fit. This, however, is not absolutely necessary, because if the buckets do leak a little the loss will not amount to a very great deal.

After the sixteen 6-inch boards have been nailed in place, the 3-inch boards are made fast. These are arranged

to run radially along the lines drawn on the disks. Then the 9-inch boards are fitted into place. It will be found advisable to bevel the edge of each board so as to make a fairly close fit with the bottom of the bucket. The outer edge of each 9-inch board may be smoothed off flush with the rim of the wheel, after it has been nailed in place. Holes should be bored in the two disks to let out the water that might leak in through cracks in the buckets.

A wheel such as this ought to have a great deal of power, provided there is water enough to keep its buckets

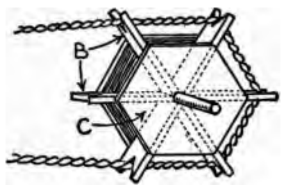
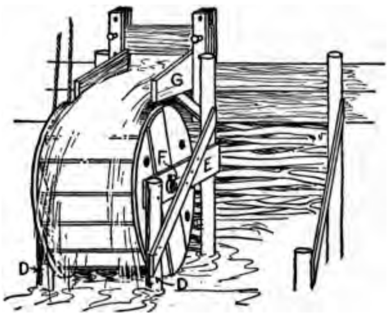


FIG. 180.—The rope pulley

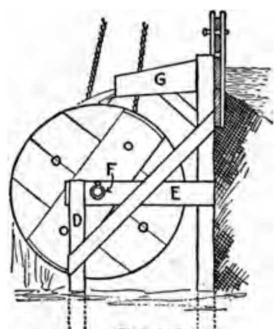
well filled. If we are to use this power, we have to fasten a pulley on the face of the wheel, because the wheel is to turn idly on the shaft. The best form of drive is a rope belt, which calls for the use of a V-grooved pulley. A rope pulley does not necessarily have to be circular. A very good wheel can be made of the form shown in Fig. 180, which consists of six arms, B, each ending in a V-notch, in which the rope runs. These arms are held firmly in place by means of side pieces, C. This form of pulley gives a much better grip on the rope and prevents the rope from sliding, although it does have a tendency to wear away the belt. If the full power of the wheel is to be used, this form of pulley is desirable, particularly as the rope belt must be compar-

atively slack, as it will be likely to swell and shrink a great deal as it is exposed to the weather.

Mount the wheel below the dam in bearings built as illustrated in Figs. 181 and 182. Two piles, D, at the toe of the dam, project about 30 inches above the surface of the water, and short pieces of plank, E, extend from them back to the main piles of the dam. The shaft of the wheel passes through holes in these planks, and it is held from sliding out of the



FIG·181



FIG·182

FIGS. 181 AND 182.—How the wheel is mounted

bearings by means of collars, F, secured with set screws, as shown in Fig. 179. The wheel must be supported so that it just clears the water at the foot of the dam, which will bring the top about one inch below the crest of the dam, and it should be placed directly in line with one of the gates. Here a trough or penstock, G, must be built. This penstock need be only slightly inclined, because the water should flow but little faster than the rim of the wheel travels. The impact of the water is not depended upon to drive the wheel, but the weight of the water in the buckets. The

wheel will turn comparatively slowly, but powerfully. Of course, the penstock should be fully as wide as the wheel, and it ought to be long enough to deliver the water just back of the center line of the wheel.

The power derived from this wheel may be used for a number of purposes. For instance, if our machine shop is located near the dam, all the machinery can be driven by this water wheel, for it should develop considerable power.

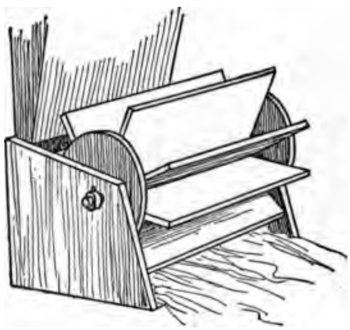


FIG. 183.—The sawmill wheel

Of course, it is not necessary to build the water wheel directly under the dam. If we wish, we may build a flume from the lake to a point near where our lighthouse is built, and place our wheel there so that its power can be used either to pump water into the reservoir at the top of the lighthouse or else to drive the lantern direct. The flume consists of an open trough which should be slightly wider and deeper than the chute which we just described, and there should be a gate in the flume at the intake end so as to cut off the flow of water when any repairs of the flume are necessary or when it is desired to stop running the wheel.

The Sawmill Wheel

There is another type of wheel which may be found very convenient, although it does not give the power that the overshot wheel does. However, this wheel is very easily constructed, and no doubt it will furnish all the power that we may need. It is known as a sawmill wheel, and consists of a small wheel about 1 foot in diameter, which is

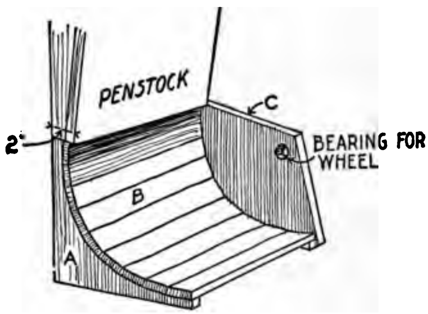


Fig. 184.—Chute for the sawmill wheel

driven mainly by the velocity of the water at the foot of the dam. This wheel is illustrated in Fig. 183. It consists of boards 6 inches wide and 2 feet long, which are set radially about a central shaft and fastened in place by means of wooden disks at each end. The water passes under this wheel and strikes against the projecting blades on the under side. Leading from the top of the dam is a square wooden pipe 2 feet broad and narrowing from 1 foot in depth at the upper to about 2 inches at the bottom. This chute is made of two pieces of board, A, Fig. 184, which are cut out on a curve such as that illustrated, and these are

floored with narrow strips of wood, B, after which side pieces, C, are nailed fast just far enough apart to clear the projecting blades of the sawmill wheel. The wheel is mounted in these side boards.

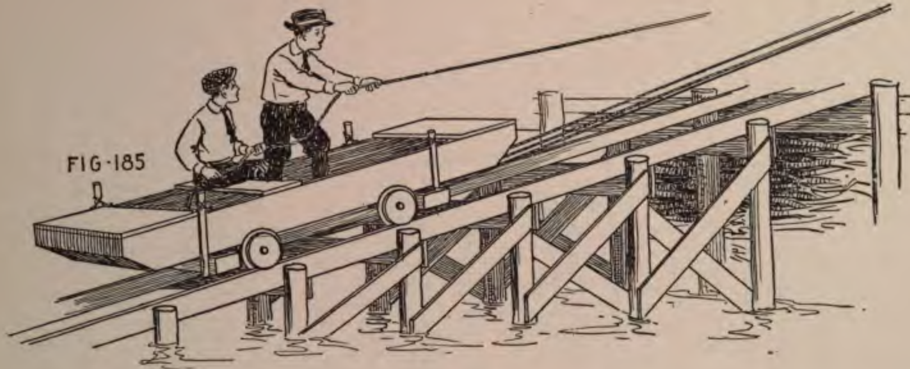
As the water rushes out of the tube, it strikes the blades and drives the wheel around not only by its impact against them, but also by its weight upon them. This wheel necessarily travels at a fairly high speed. Its power may be utilized by attaching a pulley to a projecting end of the shaft and connecting this by means of a rope belt with the machinery that is to be driven.

The Boat Elevator

Now that we have constructed our dam, we can build the inclined elevator to haul our boats over the top. The incline should be about three times as long as it is high. If the lift is 5 feet, the incline should be about 15 feet long at the base.

If a suitable incline can be cut in the bank, well and good. Otherwise we shall have to bring our piledriver into service to drive a double row of piles along the line of the incline, setting each pair about 3 feet back of the pair previously driven. Because of the weight of the scows, this structure will have to be very solidly constructed, and it should be braced thoroughly, as shown in Fig. 185. One-inch boards 4 to 6 inches deep should be nailed to the posts. These should project slightly above them, so as to form rails upon which the wheels of the boat carrier may run. This carrier consists of a long, low car, with flanged wheels, constructed after the manner of those used in the gravity

FIG·185



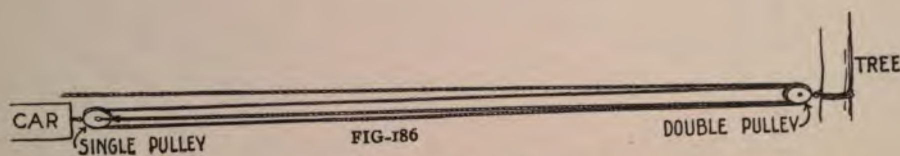


FIG-186

FIGS. 185 AND 186.—The boat elevator

railroad. The wheels may be 6 or 8 inches in diameter at the tread, and the car should be about 6 feet long or about half the length of the longest boat that it is to carry. The car will have to be wide enough for the wheels to clear the boat. Fig. 185 illustrates the car in service. It should be furnished with stakes at each corner to which the boat may be lashed. The car will have to be weighted with a box of sand at each end to keep it from floating when it is not carrying the boat.

The inclined railway will have to extend far enough into the pond to permit the boat to be floated over the car when the latter is at the lower end of the line. The car is connected by pulley and tackle with a tree on the bank above the dam. By the use of a double pulley at the tree, arranging the tackle as in Fig. 186, the power exerted by a boy pulling on the rope will be increased three times, so that it will be easily possible for him to sit in the boat and draw himself slowly up the incline over the crest of the dam and into the water of the upper lake. When going from the upper level to the lower, the car can easily be hauled over the crest of the dam, because the incline is slight, after which it will run down by gravity to the water below. In fact, this will furnish an interesting form of "shoot the chutes" from which a great deal of pleasure can be had.

CHAPTER IX

BUILDING CONSTRUCTION

WICKER HUT. THE STRAW LOOM. STRAW THATCHING. STRAW HUT. MASONRY. STONE CHIMNEY. BRICK MAKING. A FLAT BRICK ARCH. A BOTTLE WINDOW.

WHILE we have done a great deal at our lake, improving navigation upon it, providing roads around it, and utilizing the power of the stream that flows into it, we have not yet furnished ourselves with any form of shelter for the night, should we wish to camp there. A woodsman is never bothered very much about preparing a temporary shelter. He can make a lean-to very quickly by putting a pole across the low branches of two trees, resting a set of slanting sticks against the pole and laying a thick thatching of branches on the sticks. But we shall want something a little more permanent than this.

WICKER HUT

There are several ways in which a substantial shelter can be built without boards and nails. If there is a plentiful supply of willow to be had, we can make a wicker hut. While willow is the best material for such a hut, there are other kinds of wood than can be found in long pliable rods or withes in almost any wooded region.

First we must cut a quantity of stakes or posts about 2 inches in diameter. The number will depend upon the

size of our hut. If it is to measure 6 by 8 feet, we shall have to have 39 posts. They will have to be driven into the ground 8 inches apart, leaving a space of 32 inches for a doorway in one of the 6-foot sides. We are going to have a slanting roof and so we can make one of the 8-foot walls 6 feet high while the other need not be more than 3½ or 4 feet high. The stakes will have to be cut accordingly, but

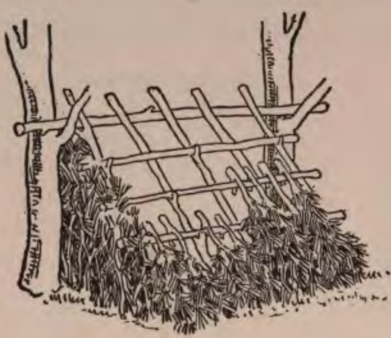


FIG. 187.—A woodsman's lean-to

we need not saw them off until the filling of willow withes has been woven in. The withes should be stripped of leaves and soaked in water to make them pliable. Then, starting at the doorway, a withe is doubled around the doorpost and the two ends are woven in opposite directions around the posts as far as they will reach. The weaving is then taken up with two fresh withes, starting them back so as to overlap the first withe. If pliable withes are not to be had, they need not be doubled around the doorposts, but can project an inch or two beyond them. In that case, however, the

doorposts will have to be tied back to the other posts with cord or wire.

In the wall opposite the doorway an opening is left for a window. This should be placed high up where it will be sheltered by the roof. It need not be more than a foot deep and 16 inches wide, a width equal to the space between two posts. The window is only intended to furnish light. It is

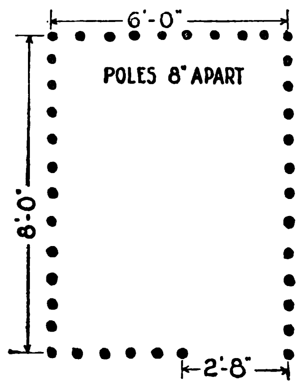


FIG. 188.—Plan of the wicker hut

hardly needed for ventilation, as the walls will be quite porous.

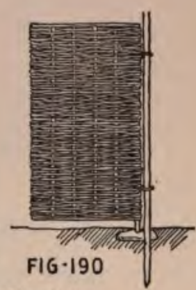
A wicker door can be made of carefully selected withes woven about a set of 1-inch sticks set about 6 inches apart with a heavier stick at the hinge side. This hinge stick should project below the others so that it can rest and turn on a flat stone buried in the ground and yet hold the rest of the door clear. The door is then lashed to the doorpost with rope near the top and bottom, as shown in Fig. 190.

The roof is now woven in a broad slab 9 feet wide and 10 feet long so that it will overhang the walls on all sides, and it is fastened in place by tying it at each post.

This hut as it stands is not rainproof, but it can be made so by thatching it with straw as explained below.

The Straw Loom

The soldiers in the great European War have had to use a great many makeshifts in order to make their quar-



FIGS. 189 AND 190.—Construction of the wicker hut

ters in the trenches livable. Some of the emergency devices that they have invented can be easily made by boys and will be found very useful in the camp. A recent book on suggestions for the guidance of soldiers tells of an ingenious device used by the British to provide their dugouts with suitable flooring and bedding. Soldiers used to be furnished with a quantity of straw on which they could make their beds and which they could spread over the floor. The straw, however, was liable to be trampled into the earth and scattered about so that it made more of a litter than

a good flooring; and so some brilliant soldier devised a simple loom with which the straw could be woven into mats.

Fig. 191 shows how this loom is constructed. Two posts, A, are set up in the ground, as far apart as the desired width of the mat, and they were connected at the top, about three feet from the ground, by a cross-rail, B. Let us suppose that the mat is to be 3 feet wide and 7 feet long, or about large enough for a bed. The posts would then be set a little more than 3 feet apart. Six feet

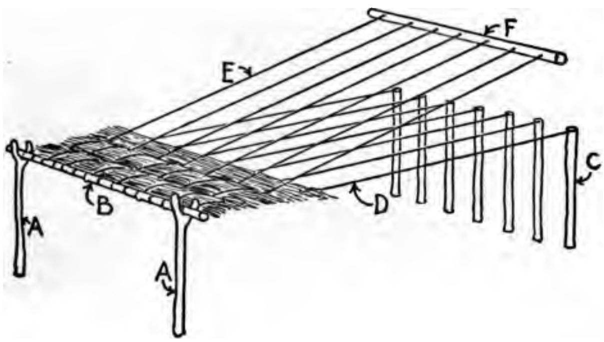


FIG. 191.—The straw loom

in front of them a row of seven posts, C, would be planted in the ground 6 inches apart, and lines of twine, D, would be tied to them. These would be extended back to the rail, A, to which they would be firmly secured, keeping the lines parallel to each other. Between these lines other lines of twine, E, are fastened, and are to run to a bar, F. The lines E must be a little more than 6 feet long, so that the bar may be moved up and down past the row of posts, C.

This is all there is to the loom. It takes two to operate it. While one raises the bar, F, the other lays a quantity

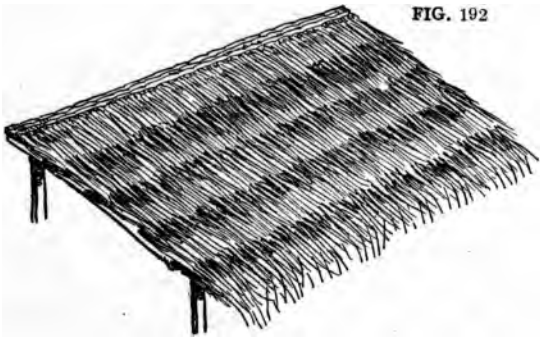
of straw on the lines D, but under the lines E. Then the bar F is lowered and another quantity of straw is placed between the lines, but under the lines D. Thus the weaving proceeds with the straw placed alternately above and below the fixed lines D. As each batch of straw is put into place, it is beaten up against the finished part of the mat by means of a rod, or "beater," so that the mat will not be woven too loosely. After the weaving is done, the fixed lines of twine are tied to the movable lines and the mat is trimmed neatly along the sides with a large pair of shears. Along each edge of the mat, it is quite important that the movable line lie close to the fixed line. In fact, it would be well to have the lines E double, with a strand on each side of the fixed line, so as to bind the straw very securely at each edge. Mats of this sort can be made in any size to fit the floor of the hut or for a bunk.

Straw Thatching

This method of weaving mats suggests a simple way of binding straw so that it can be used for the roof of a hut or even for the sidewalls. The same sort of a loom can be built, using narrow sticks for the row of posts and setting them very close to each other so that the lines will not be more than an inch apart. Three fixed lines and four movable ones will suffice. With such a loom the straw can be woven into a strip that is bound fast along one edge, while at the other side the straw will hang as a broad fringe. To support the straw while it is being bound, a board should be mounted beside the loom so that it will just clear the twine. Bands of straw such as this can be fastened to the

roof of the hut, starting at the lower side, with the fringe hanging downward, laying each successive band so that the loose straw will overlap the bound edge of the band previously laid (see Fig. 192). The straw will have to be rather

FIG. 192



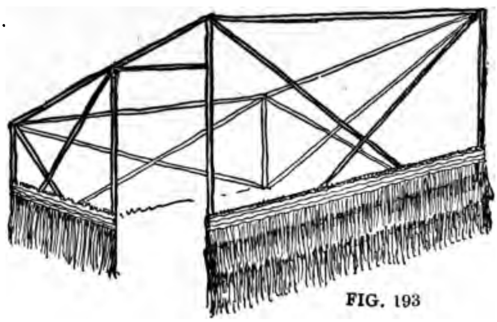


FIG. 193

FIGS. 192 AND 193.—Straw thatching

thickly laid so that it will be sure to shed water. The sides of the hut may be sheathed in the same way to keep out the rain. As a matter of fact, we could make the entire hut of straw, dispensing with the wicker work except on the roof, where it will be needed to support the thatching.

Straw Hut

If the entire hut is to be made of straw, a framework of posts must first be set up. These should be planted firmly in the ground, and the posts should not be more than 18 inches apart. To make the framework secure, the corner posts should be braced with sticks running diagonally and tied to the adjacent posts, as shown in Fig. 193. Bands of straw may then be fastened to the framework, starting with the bottom of the wall and working upward, so that each band will overlap the one below. The bands are tied fast at each post. The door may be of wicker covered with straw.

The straw loom will be found useful for other purposes as well. For instance, it can be used to fasten the ends of branches together for a temporary lean-to or shack. When the branches are bound together, it will be much easier to secure them in place on the slanting sticks of the lean-to than the careless method of piling them on and trusting to luck that they will stay where put.

Masonry

Instead of using wicker-work and straw for the walls of our hut, we may use stone. It is quite an art to build a stone wall without mortar, but it can be done if the stones are carefully selected and small stones are wedged into the chinks between the larger ones. But maybe we can get hold of some lime and make some mortar. Then we can build a real stone wall.

To mix up a batch of mortar, we must first construct a shallow box, or make a broad wooden platform, of three or four boards fastened together with battens or wooden strips on the under side. The joints between the boards should be water-tight. Next we must get some good sharp sand. The sand must be clean, that is, it must have no mud or clay in it so that when the sand is washed the water must be clear and not muddy. To mix mortar we must have three pails of sand for each pail of lime. Place the sand on the platform and scoop out a pit in it to receive the lime. Then sprinkle the lime with water, putting in two to three parts of water for each pail of lime. Cover the lime with a layer of sand and let it stand for twenty-four hours to slack. Do not disturb the lime while it is slacking. At the end of the twenty-four hours the lime will be ready to have the sand stirred into it. This is done with a spade. The lime and sand are turned over and over with the spade until the mass is thoroughly mixed. Sand is added until the mortar is fairly thick. Now we can go ahead with our stone wall. We ought to have a mason's trowel, but we can get along with a small flat shovel shaped out of a piece of wood. In building the wall, we must be sure to use the mortar sparingly. Its only purpose is to cement the stones together. Each stone must be covered with mortar, and so a good thickness of mortar must be laid on the wall and the stone must be pressed into it, but we must not use mortar to fill up big chinks in the wall. All the gaps between big stones should be filled with little ones.

Stone Chimney

It will take a lot of mortar, a lot of stone and a lot of patience to build a stone hut. In fact, it will be too big a job for most boys to undertake, but there is no reason why a fireplace and chimney should not be built out of stone.

When we build a chimney, we must remember to carry it well above the roof of the hut. But probably the hardest part to build will be the arch above the fireplace. We shall

FIG. 194.—Using a barrel as a form for a fireplace

have to have a form to support the arch while it is being constructed, and probably the handiest form will be a barrel. The sides of the fireplace must be set just far enough apart for the barrel to fit between them. The barrel should be set up on a couple of boxes, so as to bring it high enough (see Fig. 194) and it should be blocked with stones to keep it from rolling or teetering. Then the stone wall is built over the barrel, taking care to select stones that will fit closely, and if possible, to get a wedge-shaped stone for the keystone at the top of the arch. If the stones are care-

fully selected, they will hold the arch without the use of mortar, but of course we shall use mortar in our arch, only making sure that we do not depend too much upon the mortar to keep the arch from falling.

Brick Making

Another material of which a fireplace can be built is brick. Of course we cannot afford to buy brick, but there is no reason why we should not make it out of the clay that is to be found along the banks of our pond. To be

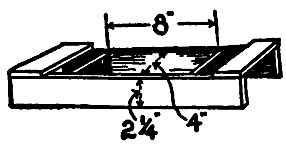


FIG. 195.—Brick-mold

sure we cannot attempt to make fire-baked brick, because this calls for a much greater heat than it is possible for us to get on a small scale. But there is no reason why we should not use sun-dried bricks. In certain regions of the country a clay is found which will make a very durable brick after it has been baked by the sun. The ordinary clay, however, does not make so hard a brick that it will stand up in a rain. The brick may seem very firm, but as soon as the water touches it, it turns to mud. Nevertheless we can make clay or even mud bricks and then protect them with a material which will prevent them from being worn away by rainstorms. Common clay will not hold together very well unless it is fire-baked, but we can

overcome this difficulty by using material that the old Egyptians used in Bible times, namely chopped straw.

First we must make a mold for our brick. This can be constructed as shown in Fig. 195. It will be seen to consist of a small box open at top and bottom, into which the clay is placed. The mold should be 8 inches long, 4 inches wide and 2¼ inches deep. The clay is prepared by wetting it thoroughly and spading it until it is a soft pasty

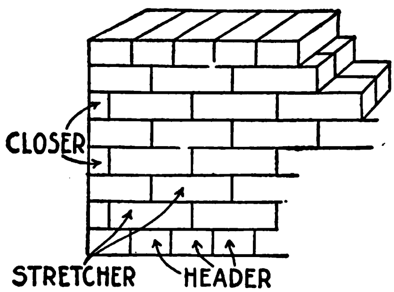


FIG. 196.—Bricks laid in the American bond

mass, and then mixing in a quantity of chopped straw. The regulation method of doing this in the East is to tread the clay with the bare feet. While this is a rather dirty job, nevertheless it is about the best way to get a thorough mix without using a machine for the purpose. After a quantity of clay has been prepared, which may be done in a pit right at the clay field, a board is laid on the ground, the mold placed on the board, and a quantity of clay is introduced into the mold. This is firmly pressed into place and then the mold is lifted off the clay, leaving it on the board to dry. The board loaded with bricks must be laid

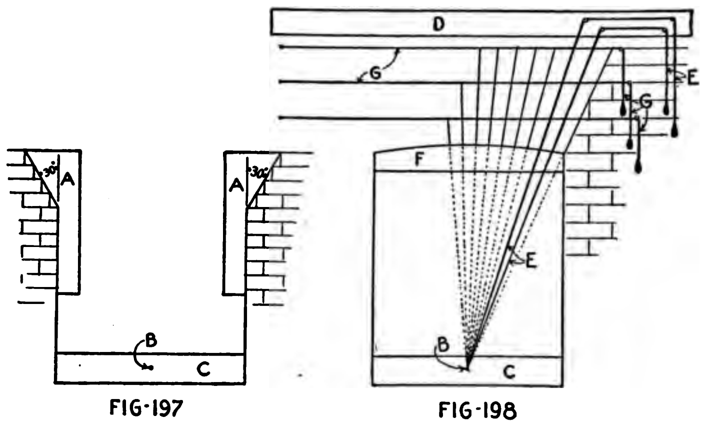
out in a position where it will get the sun. The bricks must be covered up at night to prevent rain from touching them.

After a quantity of bricks have been prepared, we may proceed to build up our brick wall. There are many ways of arranging the bricks, but we may as well use the American bond which is shown in Fig. 196. Bricks that run lengthwise of the wall are known as "stretchers"; those that run crosswise as "headers." The wall should be at least as thick as the length of the brick. Then a row or course of headers is laid, on which are placed six courses of stretchers—after which there is another course of headers and then six more stretchers. Each course of stretchers must break joints with the course just laid. In other words, the joints of a course of bricks must never come in line with the joints of the next course above or below. This makes it necessary to use half bricks or "closers" at the end of a wall in every other course of headers.

A Flat Brick Arch

Fig. 197 shows how a flat arch may be made with bricks. First a form, A, is made for use at each side of the opening so as to leave a symmetrical seat for the arch. The form should have a slant of about 30 degrees. Mark the point where the two slanting lines meet, with a nail, B, driven into a board, C. Above the arch another board, D (Fig. 198), is placed across the gap in the wall. Then from the point B to tacks in the board D, strings, E, are stretched, as shown, to mark the proper slant of the bricks in the arch. During construction the bricks rest on a pair of boards, F, which

ought to be slightly curved as shown. The bricks are laid on edge on the boards and have to have their upper and lower edges chipped off to such an angle that they will lie horizontal. In order to keep the lines horizontal, cords G are stretched across the opening and are kept taut by means of weights.



FIGS. 197 AND 198.—Making a flat brick arch

Whenever operations have to be stopped, the wall should be covered with heavy tar paper or some waterproof material which will keep it from being attacked by the rain. After the structure has been completed, it is protected by a coating of Portland cement. The cement is mixed with sand in the proportion of one part cement to two parts sand, and this is thoroughly wetted down until it makes a very thick liquid of milky consistency. Be sure not to use more cement than can be utilized in a half hour's time, because within a half an hour the cement will begin to set.

This cement mixture is thrown or spattered upon the brick structure by means of a short-handled broom. The wall should be thoroughly coated with cement all over the exterior. In the case of a chimney, the construction should be such that the interior will not be exposed to rain. In other words, there should be a flat stone covering the top of the chimney with chimney openings in the sides, and these openings should be thickly coated with cement to prevent the entrance of water. A brick structure thus cemented over will be able to stand up against ordinary storms for an indefinite period of time.

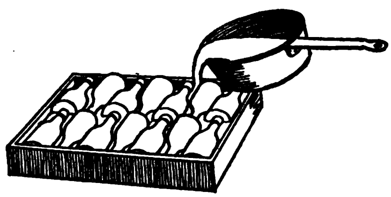


FIG. 199.—Making a bottle window

A BOTTLE WINDOW

There is another idea that we can borrow from the soldiers. In their dugouts they use glass windows, but the panes are made of old bottles bedded in cement, because window glass is hard to get and is easily shattered by the shock of shell fire. The window pane gives plenty of light, but naturally the seeing is not very good. We can make such a window, using a shallow box just the size of the window opening for our mold. The bottom of the box is filled with clay and into this clay the bottles are pressed to a little

less than half their depth. Fit the bottles in so as to leave about half an inch between them (see Fig. 199). After the clay has thoroughly dried, pour in a thin mixture of cement and sand. Care must be taken to keep the cement from smearing the bottles. Use a mixture of two parts sand to one of cement. Marble dust in place of sand will make a white, fine-grained slab. The cement should lie about an inch in thickness over the clay. After the cement has hardened, which will take about a day, the mold is knocked apart and the slab of cement with the bottles bedded in it is lifted out. The clay is washed off the back of the slab, and the window pane is ready to be fitted into the window.

CHAPTER X

ELECTRIC POWER

VOLTS, AMPERES AND OHMS. ELECTROMAGNETS. INDUCTION. DETECTING ALTERNATING AND DIRECT CURRENT WITH A MAGNET. TRANSFORMING HIGH VOLTAGE INTO LOW. CONSTRUCTION OF A "HEDGE-HOG" TRANSFORMER. SHELL TYPE TRANSFORMER. HOW TO MAKE AN ARC-LAMP. ELECTRIC WELDING. MOTORS AND DYNAMOS. A PRONY BRAKE. HYDRO-ELECTRIC POWER.

ELECTRICITY is used so much, these days, and in so many ways, that no one can claim to be an all-around engineer who doesn't know something about it. Now it is not likely that there are many boys fond of tools and of making things with their own hands who haven't dabbled in electricity, at least to the extent of putting up a door bell or connecting up a toy motor or an electric train. But a boy can do all this without having the slightest notion of the very elements of electricity, and so we shall have to begin with the A B C of the subject. Those who have graduated from the elementary part of electricity can skip the next few paragraphs.

We might start with instructions for making electric batteries, but this would be a waste of time, because dry batteries can be bought so cheaply that it would not pay to make them. We are going to assume, then, that any reader of this book who has occasion to use a small amount of current can buy or borrow a battery for his requirements.

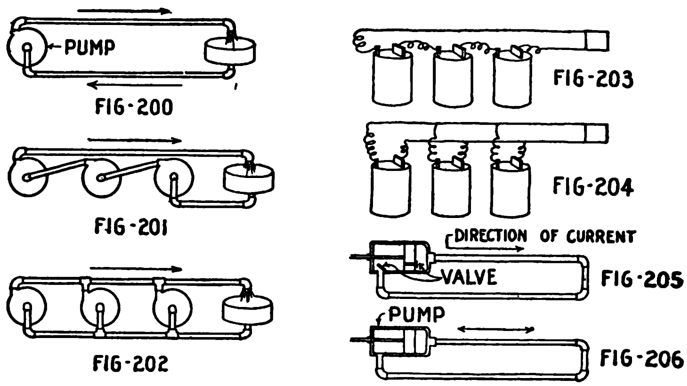
Now in the first place what most people mean by a battery is really a cell, and it takes a number of cells to make a battery. There are different ways of connecting up the cells, depending upon whether we want a small high-pressure current or a large low-pressure current. The pressure of an electric current is measured in *volts* and the size of the current in *amperes*. Now these two words, *volt* and *ampere*, and also another term, *ohm*, are used very frequently in electrical work, and unless we understand just what they mean we may as well not attempt to do any electrical work.

Volts, Amperes and Ohms

Electricity is such a mysterious energy that it is rather hard to understand it unless we compare it with something that we can see or feel. Suppose we imagine that the current that goes through a wire is like a stream of water in a tube. Our battery is then a pump that forces the water through the tube. Fig. 200 shows such a water current system in which a rotary pump is used to represent the battery because it operates continuously instead of by strokes like a piston pump. The more powerful the pump the higher the pressure in the tube, and it is this pressure that is called voltage when we have to do with electricity. Now if we have three pumps and connect them as in Fig. 201, the pressure will be tripled. Suppose each pump is capable of producing a pressure of two pounds, working together in series they will produce a combined pressure of six pounds. If the pumps are connected in parallel, as in Fig. 202, the pressure in the tube will remain at two pounds, but

there will be a larger flow of water. In the same way, if we connect up a battery of cells in series, as in Fig. 203, we shall have a higher voltage, while if the battery is connected in parallel, as in Fig. 204, the flow of current will be larger; in other words, there will be a larger amperage.

In our pipe line, there is another measure that we must consider. If water is forced through a pipe of very small



FIGS. 200 TO 206.—How electric current systems resemble water current systems

diameter, it does not flow as readily as it would in a pipe of larger diameter, because of the friction of the water against the sides of the pipe. This resistance to the flow of water in a pipe line has its equivalent in the electric circuit in what we call the electric resistance which is measured in ohms. If we try to force an electric current through a fine wire, the amperage will be cut down. If the wire is short, and we have a high pressure voltage, it will force through more current than the wire can carry, and the wire will grow hot. The flow may be enough to melt the wire. But

if the same wire is very long, there will not be enough pressure to force the current through and consequently there will be a smaller flow of electricity through the wire. And so there is always a relation between the volts and the amperes and the ohms.

We can always tell how many amperes are forced through a wire when we know the pressure or voltage and the resistance of the wire in ohms, because all we have to do is to divide the volts by the ohms and that will give us the amperes. In other words, if we have a wire that offers a resistance of 100 ohms, and we have a pressure of 250 volts, we divide 250 by 100 and find that the number of amperes that go through will be 2½. In an electric lamp of the incandescent type fine wires of tungsten or other metals are used which offer so much resistance to the current that is forced through them that they become white hot. If they were out in the open air they would burn immediately. But you cannot burn anything without supplying it with oxygen, and so these wires are placed in a bulb from which all air is exhausted so that there is not any oxygen in there to consume the wire.

Electromagnets

One of the most important things in electrical work is the fact that a current not only passes along the wire but also has an influence on its surroundings. We find this out when a wire through which electricity is flowing is brought near some iron filings. The iron filings will turn at right angles to the direction in which the current is flowing. This is what we call "magnetism" and it consists

of invisible lines of force running around the wire. If we take this wire and wrap it up in a coil the effect on the iron filings will be increased, because each turn of the coil will add its effect. Such a coil, if it consists of many turns, will be powerful enough to lift a small piece of iron and draw it into the coil. Such a coil we call a " solenoid," and if we place a core of iron inside the coil we have an electromagnet. In other words, it will have the same action as the solenoid, but a much more powerful one, because the iron core gives a better path for the magnetism than the air core of the solenoid.

Induction

This leads us to still another phase of electricity which every boy should know before he can proceed with electrical work, and that is the fact that a current in one wire may set up a current in another wire that is entirely disconnected from it. If we have two parallel wires, in one of which a current of electricity is flowing steadily, there will be no evidence of electric energy in the second wire. But when there is the slightest disturbance in wire No. 1 there will be a sympathetic flow of electricity in wire No. 2. If, for instance, the flow in wire No. 1 is reduced in voltage, immediately a sympathetic current will be set up in wire No. 2, and if the current in wire No. 1 is suddenly increased in voltage, this also will set up a current in wire No. 2. These sympathetic currents are called induced currents, and we say that one wire affects another by induction. The induced currents flow only while the variations in wire No. 1 are going on. It is this principle that is used in cut-

ting down the voltage of a-current that is too high for our use or for actually increasing the voltage of a current that is too low to do the work we wish it to, as will be explained in a moment.

There are two kinds of electricity in use, one called "direct current" in which the current is always flowing in the same direction, and the other called "alternating current" in which the current is moving back and forth very rapidly. The water pumps and pipe lines in Figs. 205 and 206 will help us to understand the difference between the two kinds of current. In Fig. 205 the pump and plunger is fitted with valves so that it will make the water run always in the same direction, while in Fig. 206 the plunger and pump has no valves and so the water surges back and forth. This surging is felt throughout the pipe even when there is no general circulation of water. That is exactly what takes place in an alternating current in electrical work. Now a wire in which alternating current is surging sets up sympathetic pulsations of electricity in any other wire that happens to be near it and parallel to it.

Detecting Alternating and Direct Current with a Magnet

In the earlier days of electricity direct current was used for lighting purposes. Now alternating current is commonly used, but in some of the older cities and in certain private installations we still find direct current. It is well for us to know what sort of current we have at our disposal in the lighting system before we can make use of it.

As we stated above, an electric current flowing through a wire affects iron filings, and on the other hand, a magnet will affect a wire through which electricity is flowing. And so, if we make an ordinary horseshoe magnet and hold one of its poles against the bulb of a lighted electric lamp, we shall see the filament of the lamp drawn to one side or the other, if direct current is flowing through it, and if alternating current is passing through it, it will vibrate so fast that it will appear to grow thick, like the string of a violin when the bow is passed over it.

Transforming High Voltage into Low

In the ordinary lighting circuits, 110 volts pressure is used. Now 100 volts is entirely too high a pressure for a boy to fool with. It is liable to give one a very severe shock and under certain peculiar conditions it might even kill a person. If we are to use the current from our lighting circuit, we must cut down the pressure to something much safer; besides, 100 volts would be entirely too heavy a pressure for an electric bell or for any small electric devices, toys, Christmas tree lamps, etc., that one is liable to use on a battery circuit. But it is a comparatively simple matter to build an apparatus which will cut down the pressure by means of induction. Such an apparatus we call a transformer. It consists of two coils of insulated wire wound one upon the other. The coil connected to the lighting mains is called the primary and the other the secondary. If we have as many turns of wire in the primary as in the secondary, then the induced current will have practically

the same voltage and amperage as the primary current. But if the number of turns of wire in the primary are twice as many as those in the secondary, the voltage in the secondary will be only half of that in the primary while its amperage will be twice as great as that in the primary. If, on the other hand, we have half as many turns of wire in the primary as in the secondary, the voltage will be increased and the amperage will be reduced proportionately in the secondary. As we explained before, every electric current is accompanied by some sort of magnetic effect, and this plays an important part in induction, so that if we increase the magnetic field around the coil of wire we shall increase the inductive effect on the secondary coil. And so, in our transformer, we shall have to have an iron core around which the primary and secondary wires are wound, and it will be well to carry this iron core back over the outside of the wire windings as well.

Construction of a "Hedge Hog" Transformer

The following instructions for making a transformer, if carried out, will produce a very efficient piece of electrical apparatus which will serve for short telegraph lines, miniature lamps, small electric motors, Christmas tree lamps, etc. It is a piece of apparatus that requires no attention at all and uses up very little energy. It is the type of transformer known as a "hedge hog," consisting simply of two coils of insulated copper wire wound one on top of the other on a spool through which passes a bundle of bare iron wires.

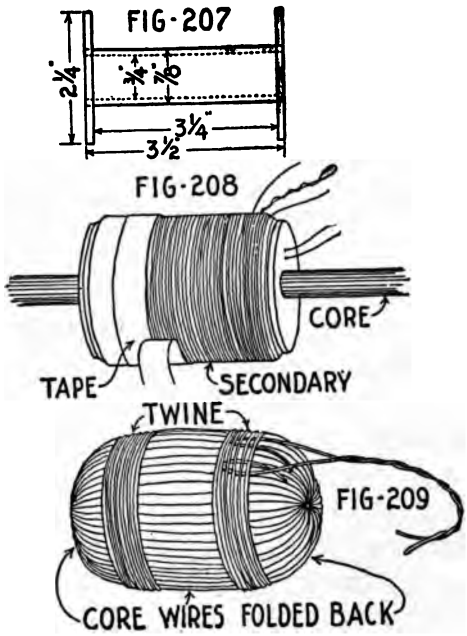
The dimensions of a suitable spool upon which to wind the coils are given in Fig. 207. The spool is best made in the lathe by turning it out of a solid piece of hard wood, but a good one can be made by gluing two wooden heads on a tube formed by wrapping several layers of stiff paper around a ¾-inch rod.

For lighting circuits of about 110 volts, 60 cycles, the primary coil should be wound with 4800 turns of No. 28 wire, which will weigh about one pound. One of the best kinds of insulated wire for this purpose is that having a covering of enamel protected by one of cotton. Wind the wire in smooth, even layers like thread on a spool, passing the ends out through holes in one head.

The secondary coil is to be wound on top of the primary coil, the latter being first covered with two layers of oiled muslin, or of cotton cloth tied down with thread. For eight volts there will be needed in the secondary coil 400 turns of No. 18 double cotton covered magnet wire, of which about 1⅜ pounds will be required. This is most conveniently put on in eight layers of fifty turns each, which allows of a loop, or tap, being brought out at the end of the fourth layer, or middle of the coil, from which four volts may be obtained by connection to it and to either one of the coil ends. Fig. 208 shows the primary with its two fine wire terminals sticking out through the head, and the secondary coil on top with its three connections.

For the core of the transformer about three-fourths pound of No. 20, or finer, soft annealed iron wire is required, cut in pieces about 10½ inches long, and carefully straightened. The ¾-inch hole through the coils should be

packed with as many of the pieces of the wire as it will hold. This also is shown in Fig. 208, together with a part of a necessary covering of cotton tape for the protection of the secondary coil.



FIGS. 207 TO 209.—The "hedge hog" transformer

The next step in the construction is to bend the ends of the iron wires around as shown in Fig. 209, so that they overlap and completely inclose the coils except for a small space where the coil ends come out. The iron wire ends must be drawn down in place and bound with several wrappings of twine as shown.

The terminals of the primary coil are so delicate that they are always liable to be broken off, thus spoiling the entire apparatus. To guard against this mishap it is advisable to bind a piece of lamp cord to the core in the position shown in Fig. 209, and afterward to connect the ends of the primary wires to this cord, preferably by soldering them, thus relieving them of all strain.

To protect the transformer from dampness and from mechanical injury it is a good plan to warm it slightly in an oven, place it upright in a suitable glass jar, and pour in enough melted paraffine to cover the core and soldered connections.

The lamp cord terminals are to be permanently connected to the 110-volt alternating current mains, while the secondary terminals go to a bell circuit in place of the battery wires. Bells of ordinary size will ring well on four volts, obtained from one secondary terminal and the middle loop, while for those that are larger, or on longer lines, eight volts is available from the two outside terminals. For Christmas-tree lighting with a dozen 3½-volt battery lamps, connect one-half of the lamps to each half of the transformer secondary.

During the long periods that the transformer is idle it draws so little power from the lighting mains that it will not actuate the ordinary meter, so that the latter registers nothing for the transformer losses except at such hours of the day as current is being drawn for other purposes also. On the basis of current being used for house lighting an average of four hours a day, with nothing but the ring-

ing transformer in circuit during the other twenty hours, the transformer losses will be but 20 cents a year.

Shell Type Transformer

Another type of transformer which will be a little more powerful may be made as follows: This transformer is what is known as the shell type which is somewhat similar to the hedge hog in the fact that the core is extended so that it is carried completely around the outside of the windings. In this transformer we wish to reduce the voltage of our lighting circuit down to about 20 volts, and we wish to have a flow of 10 amperes in our secondary, because this will give us a goodly supply of current with which we can light a small arc-lamp and use the carbon pencils of the arc-lamp for welding small pieces of metal.

Instead of wire for the core of this transformer we shall use band iron about 1¼ inches wide. Iron is sold in this form but if it is difficult to obtain, it can be cut out of ordinary stove-pipe iron. The iron should be very soft and thin, and if it is slightly rusty so much the better. If we cannot get stove-pipe iron, tin cans will provide a substitute. The cans may be placed in the fire to melt the solder and open their seams. Then they are opened out and cut into strips. The tin plate will be melted off and the thin sheet iron will be blackened, but that will be an advantage because it will help to insulate the strips from each other.

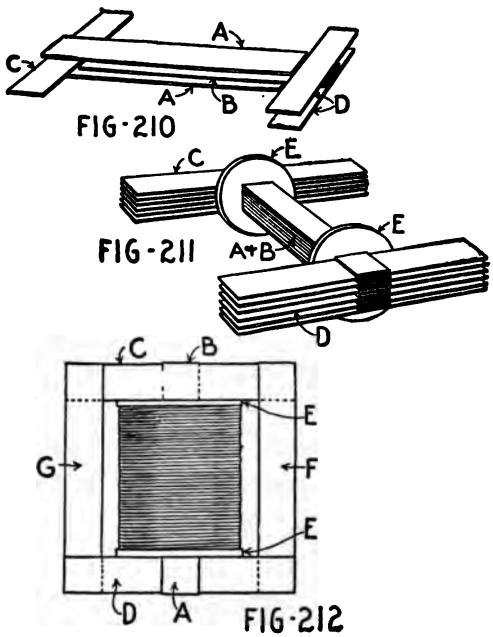
First we must cut out a number of pieces 6½ inches long, enough to make two piles 1¼ inches high, and a set of 5½-inch pieces enough to make two piles ⅝ inch high.

One of the 1¼-inch piles is laid aside for the time being, and the other three piles are arranged in the form of the letter "I," as shown in Fig. 210. The main body of the core is made up of the strips A and B, which are staggered so that at one end the B pieces project 1½ inches beyond the A pieces while at the other the A pieces project beyond the B pieces. Between these projecting pieces are placed the cross-pieces C and D, until the pile is assembled to a height of 1¼ inches.

It will be better not to assemble the pieces D until all the rest of the pieces have been assembled, as this will enable us to slip on the main body of the core a couple of spool heads E, Fig. 211. These are cut out of heavy cardboard and are 2½ inches in diameter, with a hole in the center 1¼ inches square, or just large enough to fit over the body of the core. The core is now wrapped with a layer of tape well coated with shellac and the pieces D are fitted into place. A temporary wrapping of tape will help to hold the pieces C and D in place while the primary and secondary coils are wound on.

For our primary wire we shall need to have 520 turns of No. 24 double-cotton-covered copper wire. This will take a little more than a third of a pound of wire. This should be wound on in four layers of 130 turns each. The ends of the primary are made fast to a stranded electric-light cord, as in the hedge hog transformer. This should be fitted with a plug that can be screwed into an electric-light bulb. Then over the primary a couple of layers of tape are laid well coated with shellac varnish. Be sure to have

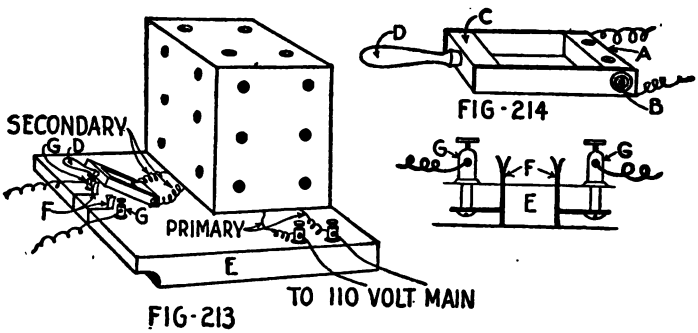
the turns of tape overlap so that there will be no danger of a short circuit from the primary to the secondary. The secondary coil is wound over the primary and consists of 100 turns of No. 14 double-cotton-covered wire, which



FIGS. 210 TO 212.—The shell type transformer

should weigh about one pound. The secondary is put on in two layers and after it has been wrapped with a strip of muslin well coated with shellac we can proceed to complete the core of the transformer by fitting the rest of the 6½-inch strips of iron 10″ long between the strips C and D, as shown at F and G in Fig. 212.

The transformer ought to be set in a small box in which holes are bored so that any heat developed in it will have a chance to pass off. This box may be set on a base, as shown in Fig. 213, and on this we may mount a double knife switch, the construction of which is shown in Fig. 214. The switch is made of two strips of brass pivoted to a block, A, by means of a couple of screws B. The opposite ends of the brass pieces are attached to a second block C



FIGS. 213 AND 214.—Further details of the shell type transformer

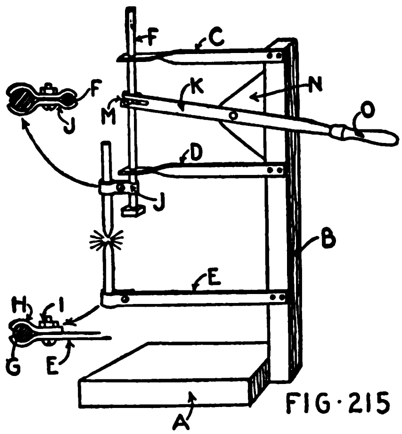
in which is fitted a handle D. In the base board there are two contact pieces E, each consisting of a piece of thin brass F doubled upon itself and slipped through a saw slot in the base board. The pieces E are held in place by means of binding screws G. The wires leading from the secondary of the transformer are connected to the screws B while the wires that lead off to the lamps or motor or other electrical apparatus we may wish to operate are connected to the binding posts G. The ends of the pieces E are spread apart so that the knives will fit between them, when the switch is moved to closed position.

How to Make an Arc-Lamp

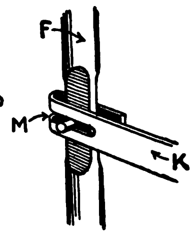
The current that we get from this transformer will be sufficiently heavy to give us a small arc-lamp. There is no great mystery about an electric arc. Two conductors are brought together and then separated slightly. Electricity leaps across the gap and shows as a very hot flame. The heat is sufficient to melt any metallic conductor and so carbon is used for the conductors or "electrodes" as they are called. The carbons are slowly consumed under the intense heat and so they must be adjusted constantly to keep the arc burning, because the flame will go out if the carbons touch or if they are separated by too wide a gap. There are automatic devices for adjusting the arc, but they are too complicated for us to operate. Instead we shall have to rig up a hand-controlled lamp.

Fig. 215 shows such a lamp. It consists of a base, A, to which is nailed an upright, B, which carries three metal straps, C, D and E. The straps C and D have a half twist in them and are bored to receive a brass or iron rod, F. This may be a long bolt with a head at the lower end. The strap E is half an inch longer than the other two and is not twisted. The outer end is bent as shown at G and a clamp, H, is secured to it by a small bolt, I. This is used to grip the lower carbon of the arc-lamp. The curve in the clamp and in the strap is obtained by laying the piece on a block of soft wood, placing a bolt or iron rod of the same size as the carbons of the arcs on the piece and then hammering the rod so as to dent the strap. The rod F carries a similar clamp which is shown in plan at J. The rod F is filed flat on each side at about the middle of its length so that it will fit a lever, K,

This is shown in detail in Fig. 216. The rod is flattened to keep it from twisting. A hole is bored through the flattened part of the rod and a pin is driven through it; this pin fits into a wide saw slot, M, in the lever, K. The lever is pivoted to a block, N, fastened to the upright and at its opposite end is fitted with a handle, O. By moving the handle up or down the arc can be regulated to a nicety. Cur-



FIG·215



FIG·216

FIGS. 215 AND 216.—Construction of the arc-lamp

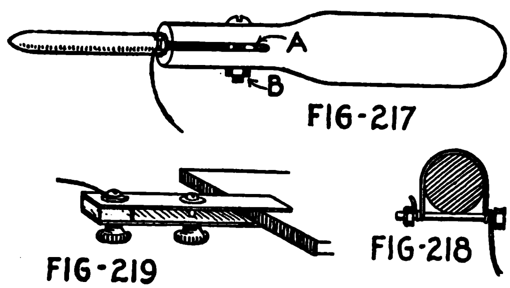
rent is led to the arc through a wire connected to the strap E and through another wire clamped between a pair of nuts on the rod F. No. 14 stranded wire should be used.

ELECTRIC WELDING

As was explained above, carbon rods are used because the arc is so hot that it will melt any metal. But we can use this heat to weld or fuse two metal pieces together. If we connect one of the pieces to one of the secondary wires

of the transformer and connect the other wire to a stick or pencil of carbon, then lightly touch the carbon pencil to the pieces where they are to be joined the metal will melt instantly, and the two pieces will be welded together.

The handle for the carbon pencil may be fashioned on the lathe out of a piece of wood. In the end a hole should be bored to receive the pencil and it should be slotted with a saw cut, A, Fig. 217, so that when the bolt, B, is tightened



FIGS. 217 TO 219.—Electric welding details

it will clamp the carbon in the handle. The wire from the transformer is connected to the carbon in the manner shown in Fig. 218. A small brass bolt is laid against the side of the pencil and the wire, bared of its insulation, is wrapped a couple of times around the bolt under the head, then passed around the pencil and wrapped around the bolt just above the nut after which it is passed again around the carbon and twisted a couple of times under the head of the bolt. Now on tightening up the nut of the bolt the wire will be drawn snugly against the carbon making a good electrical connection.

As for the other wire of the transformer we must be sure to have a good connection between it and the work that is to be welded. Various clamps can be used. A simple one is shown in Fig. 219, consisting of two brass strips connected by a couple of brass screws or bolts fitted with thumb nuts. This can readily be clamped to any thin object by tightening up the thumb nuts. The wire is connected to one of the bolts, to which it is clamped as shown between the head and a small nut.

It may be handy at times to have an electrode on a handle instead of using a clamp. This can be made just like the carbon electrode except that a piece of brass is used in place of the carbon. The end of the brass electrode should be filed off flat so that it will have a broad bearing surface on the piece that is to be welded.

Always press the brass electrode firmly against the work before the carbon electrode is touched to it or else the arc may take place at the wrong spot and the brass will be welded fast to the piece.

Motors and Dynamos

An electric motor or dynamo is a rather difficult apparatus for a boy to make, because its construction usually calls for the use of iron castings. While it is quite probable that many readers of this book could make a motor or dynamo, and would get fairly satisfactory results, the work would be far too difficult for the majority of boys and so no instructions are given here. It will be found much better to buy the apparatus. Second-hand machines can usually be picked up for a small amount, particularly direct current

machines. All direct current motors and many alternating current motors can be used as dynamos or generators to make electricity, if they are driven by some suitable power. Now we have such a power in the water wheel described in Chapter VIII. Before using this water wheel to drive a dynamo, we should know how much power we have, and the best way of measuring the power is to construct a prony brake.

A Prony Brake

Fig. 220 illustrates the arrangement of a prony belt. At A is the shaft driven by the water wheel. This may be either the shaft of the wheel, if it turns with the wheel, or the shaft of a pulley driven by the wheel. A long lever, B, is mounted on the shaft to which it is clamped by means of the strap, C, and the bolts, D. In place of the strap a block of wood could be used just as well. The lever, B, must be 5 feet 3 inches long from the center of the shaft, A, to a notch, E. Here a scale pan, F, is hung. This may be a small tin pan hung by means of three strands of twine.

We must have some way of counting the revolutions of the shaft, and this is done very easily by means of a "slapper," if the shaft is not making more than two or three hundred revolutions per minute. A piece of leather is clamped to the shaft with a loose end that will strike against a block of wood at each turn of the shaft. By counting the slaps in a quarter of a minute or less we can estimate the number of turns the shaft is making per minute.

Now a weight is placed in the scale pan and the clamp on the shaft is tightened until the friction is just enough to

raise the weight. Then the number of turns multiplied by the weight and divided by 1000 will equal the horsepower of the shaft. If, for instance, the weight is 10 lbs. and the turns 250 per minute, we have $^{2500}/_{1000}$ or 2½ horsepower.

At the end of the lever there should be a strip of wood with two stops to keep the lever from swinging too far in either direction. The shaft should be well lubricated under the clamp and the clamp must be tightened until the speed of the shaft is reduced. Having settled on the amount of power that is available we shall know how large a dynamo we can use. A dynamo is usually rated in kilowatts and not

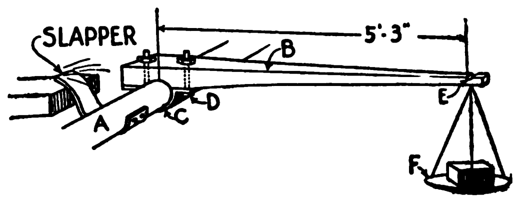


FIG. 220.—The prony brake

in horsepower. A kilowatt is 1000 watts and it takes 746 watts to make a horsepower. So a kilowatt is about 1⅓ horsepower, while a horsepower is about ¾ of a kilowatt. The watts delivered by a dynamo are the product of the voltage multiplied by the amperage. If the dynamo generates 40 amperes at 50 volts its output is 40 × 50, or two kilowatts or 2⅔ horsepower.

HYDRO-ELECTRIC POWER

The water wheel described in Chapter VIII is large enough to produce a great deal of power if there is a good supply of water, but it is not likely that many boys will have

a chance to play with a stream that will deliver a large supply of power. However, almost any stream, even one from a small spring, will supply enough power to run a small generator, say one of 50 or 100 watts. Electric motors have to run at high speed, while overshot wheels are slow and they have to be geared up by means of pulleys and belts so as to drive the generator fast enough to produce an appreciable amount of current. If a motor is to be run as a dynamo it should run a little faster than it did as a motor in order to produce all the current it is capable of generating. The current obtained can be used for lighting small electric lights and in a host of different ways. Unfortunately there is not room in this book for a list of different uses to which the current can be put; but any boy who has gone so far as to make electricity with a home-built water wheel will not be at a loss as to what to do with the current when he gets it.

CHAPTER XI

WEATHER BUREAU

ELECTRICAL WEATHERVANE. WEATHER SIGNALS. A HOME-MADE ANEMOMETER. RAIN GAUGE. THE SUNSHINE RECORDER.

Most people look upon weather predictions as more or less of a joke. That is because they remember the forecasts that are wrong and forget the right ones. Those who do have some regard for the weather bureau are apt to think that it is of service only to navigators to warn them of coming storms, or to farmers to help them in planning their work. But there are other services in which the science of meteorology is very important.

There is a railroad that runs down the coast of Florida and across the keys for miles down to Key West. This railroad runs out over the sea in long bridges that span the gaps between the keys and are very much exposed to the weather. There are times when it is dangerous for a train to run over the line, particularly in hurricane weather, and it is very important for the train operators to know what sort of weather a train is going to encounter; hence the weather is studied very carefully, and whenever a storm of any importance is predicted, train service is suspended. Then there is a block signal system controlled by the wind, which will show the danger sign when the wind mounts above fifty miles an hour.

There is another use for weather forecasts that the public does not seem to know very much about. Whenever a sudden storm comes over a large city and the sky is covered with heavy black clouds, the electric lamps are turned on in the numerous offices, and there is a sudden drain upon the electric light supply. Some of our central power stations keep observers upon the watch for such storms. They scan the horizon for thunder clouds, and when they see a storm approaching that looks as if it would blacken the sky immediately orders are given to start up the spare boilers and to put the spare generators into action, so that enough electricity will be produced to meet the coming demand. If this precaution were not taken, the lights would fail just when they were needed the most.

The Great European War has also made a great many demands upon the weather man. Our artillery officers must know something about the direction of the wind and its velocity, because when a shell is traveling six or seven miles through the air it is apt to be blown far off its course unless the gun is properly pointed to allow for the side-pressure of the wind. Now that gas is used in modern warfare, it is highly important to know which way the wind is blowing and which way it is liable to blow, for some time to come; otherwise the gas clouds might blow back upon the army that is discharging them. Airplanes and Zeppelins, particularly, must know all about weather conditions for hours to come, or they are apt to be blown far away from their objective or be wrecked if they encounter severe weather. And last of all, no modern general would attempt to make a big drive without knowing for days ahead whether rain-

storms were liable to come upon him, turn the roads into quagmires, and stall his heavy guns.

Altogether, a knowledge of the weather is a very important thing for a person to have. While it may not have any direct bearing upon engineering, we ought to have some weather knowledge in connection with our work at Big Bear Pond, because every one who camps out is more or less at the mercy of the weather and should know something about it. Of course we cannot do very much predicting of what is to come, because storms usually cover wide areas and travel long distances, and it is impossible for a person stationed at one place to know what is liable to come upon him until he sees the immediate signs of an approaching storm. But there is a great deal to be learned from the form of the clouds and the direction of the wind, and we shall have to acquaint ourselves with such weather signs. As the direction from which storms may be expected varies in different parts of the country, each boy will have to make his own study of the weather, keep a record of the direction of the wind and the nature of the clouds, and then note the kind of weather that follows.

Electrical Weathervane

This chapter on the Weather Bureau is introduced after the chapter on electric power because we expect to use some electricity in the operation of some of the instruments that we are going to make. First of all we should have a weathervane, because the direction of the wind will probably tell us more about the sort of weather that is coming than any other instrument we can devise. Our weathervane must

be placed on a tall mast where it can get the full sweep of the wind, unhampered by surrounding trees.

Any boy can make a weathervane. It consists merely of a stick of wood with an arrow point at one end and a broad vane at the other against which the wind can blow and turn the arrow into the wind. But we shall find it much more convenient to have a weathervane that we can use at night. This means that it ought to be electrically connected with an indicator in our shack or hut, so that whenever we wish we may touch a button or turn a switch and find out which way the weathervane is pointing.

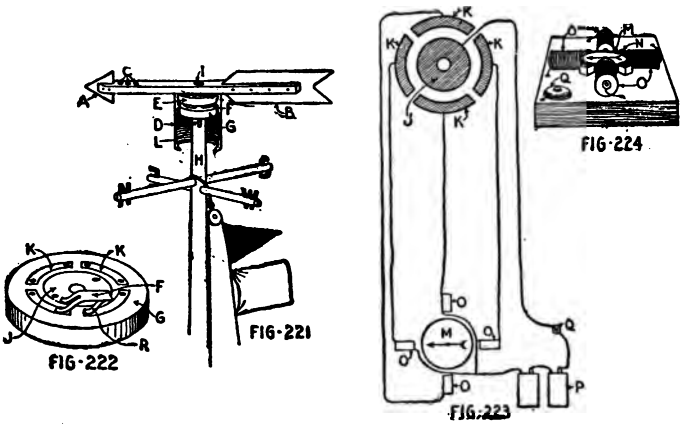
Such a weathervane can be made very simply as follows: Take a stick of wood 1 inch square and 18 inches long. Out of a piece of galvanized iron, or zinc, if that can be obtained, cut an arrow point, A, and vane, B, after the form shown in Fig. 221. If galvanized iron can not be obtained, use a piece of plain sheet iron or tin and paint it so that it will not be affected by the weather. The point of the weathervane may be inserted in a saw slot in the stick and held fast by a couple of short nails. The tail of the weathervane may be fastened in the same way in a longer saw slot.

The wood should be tapered off with a draw-knife at the tail end so as to make it lighter and in the point end holes should be bored in which buckshot or pieces of lead may be imbedded so that the vane will nearly balance at the center. But do not add too much, as it will be well to have the tail of the weathervane a little heavier than the forward part, for reasons which will be explained in a moment.

Under this weathervane we are going to make our electric connections, and to keep them from moisture we shall have to cover them with a shield that is fastened to the weathervane. This shield may be a tin can, D, turned bottom up. Cut a block of wood, E, just large enough in diameter to fit neatly inside the tin can and then fit the block and the can to the weathervane by means of a couple of screws. Take a piece of thin spring brass and bend it to the shape shown at F, in Fig. 222; then fasten it to the wooden disk, E, so that its free end will project downward and bear upon the contact plates which are to be placed on a second disk, G, mounted on the top of the mast, H. The weather vane is to turn freely on a long screw, I, which passes through a hole in the weathervane and disk E and is screwed into the disk G and the top of the mast.

The disk G must be of wood and slightly smaller in diameter than the inside of the can. On it we must mount a disk or a ring of brass, J, securing it with countersunk flat-head screws. Outside of this circle and separated from it by ½ inch we must secure four quadrants, K, of brass. The contact spring, F, that is carried around by the weathervane must be at least 1" wide so that it will bear upon the disk J and also on the plates K. The spring should be split so that when one leg is leaning on the inner contact it cannot lift the other leg off the outer ring of contact plates and vice-versa. The contact plate J will have to be connected to an insulated wire running down to our shack, while there will be four wires connected to the contacts K, as shown in diagram, Fig. 223.

We shall have to fit the disk G on the top of the mast, fastening it there by screws running diagonally into the mast so that they will hold, or else fastening it by means of angle iron, L, as shown in Fig. 221. The disk will have to be set true with the points of the compass; that is, one of the contacts K must face directly to the north. We can find the points of the compass either by the use of a pocket



Figs. 221 to 224.—The electric weathervane

compass or by use of the means described in Chapter III. When this is done and the disk G has been fastened securely, the weathervane is set in place and the pivot screw I is screwed with enough washers between disk G and disk E to support the weathervane and yet let the spring F make good electrical contact with the plates J and K. This spring comes under the tail of the vane and helps to support it. This is why the weathervane should be a little heavier on that side.

After we have proceeded thus far, holes should be bored in the top of the mast to receive ½-inch sticks which are to point to the four points of the compass. Out of pieces of tin we can cut the letters N, E, S and W, and fasten them in saw slots in the ends of these sticks, as shown in Fig. 221. Just below them a pulley should be fastened to the mast through which we can run the lines that are to carry our weather flags.

We shall have to be careful to keep the wires from the contact plates separated, so that we shall know which is which. Inside the shack we shall use a small compass for our weathervane. It is a simple matter to deflect the needle of a compass by means of small electromagnets, and so we shall have to make four magnets, one for each quadrant K. The magnets need not be large, but it is highly important that their cores be of soft iron. If a rod of soft iron ¼ inch in diameter cannot be obtained use soft iron wire, such as is employed for supporting stovepipes, care being taken to straighten out the pieces of wire. They should be 1¼" long and can be held in place by wrapping them up in a couple of layers of tape glued fast with shellac. The heads of the magnet can be sawed off a common wooden spool and fitted securely on the core. About an ounce of single cotton-covered magnet wire is wound on the core, being careful to keep the wire from kinking and laying the coils evenly and close to each other. The wire is bound in place on the core by means of tape held down by shellac, and the ends of the wire are brought out through holes in the head of the magnet.

The compass, M, may be mounted on a wooden base and held in place by means of wooden blocks, N, as shown in Fig. 224. The magnets, O, are then set radially around the compass so that they are bound down to the board by means of soft iron wire. The wires that come from the innermost layer of the magnet coils are all connected to a common wire which runs to battery, P, Fig. 223. The battery may consist of two cells connected in series. The wire running from plate J is connected to the other terminal of the battery. The compass base is now orientated, in other words it is turned so that one of the coils will point directly toward the north. This magnet is then connected with the south quadrant, K, of the weathervane and not the north quadrant, because the contact spring, F, trails under the tail of the weathervane and not the point. The magnet at the east, then, is connected with the west quadrant, and so on. In the line running to the battery a push button, Q, should be cut in. This may be of the ordinary doorbell variety.

Now suppose that our weathervane is pointing north. The contact spring in the tail of the vane will sweep over the south quadrant and will send a current of electricity through the north magnet when the button is pressed, which will hold the point of the compass in that direction. If the vane is pointing east, the east magnet will be energized when the circuit is closed, and the compass needle will point in that direction.

By providing another leaf, R (Fig. 222), to the contact spring the compass may be made to point midway between the magnets. If, for instance, the wind were northwest,

the contact spring F would close the circuit to the north magnet and the spring R to the west one. Both the north and the west magnets would be energized at the same time, and the compass needle would take up a position midway between the two, pointing to the northeast. In this way with four contacts we can get eight positions of our weathervane. Of course, if we wish to carry the subdivision fur-

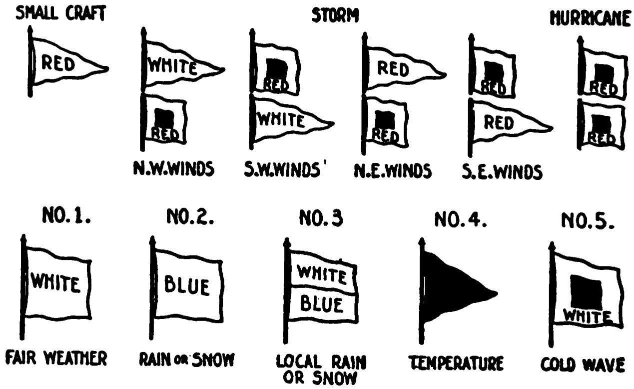


FIG. 225.—U. S. weather signals

ther, we can use eight contact sectors and in that way obtain sixteen positions for the weathervane.

WEATHER SIGNALS

We referred to the pulley on the mast which would enable us to haul up weather flags to the top of the mast. The weather flags that are used by the U. S. Weather Bureau are shown in Fig. 225. The temperature flag is a triangular blue one, and if it is placed above the weather flag it means that the day is to be warmer, while if it is placed below, that

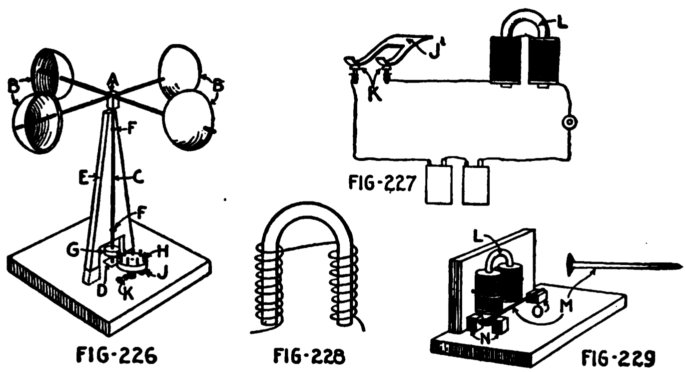
it is to be cooler. If there is to be a decided change in the weather, either a hot wave or a cold wave, the square white flag with blue center is used.

A Home-Made Anemometer

The next instrument that we shall need is called an anemometer, or an instrument for measuring the speed of the wind. The Weather Bureau recently described a simple instrument of this kind that any boy could make. The instrument is pictured in Fig. 226. The ribs of a broken umbrella are used for the cross arms, and they are passed through a block of wood, A, as shown. In the ends of the arms to catch the wind use the halves of two baby's rattles, B. These are made of paper, celluloid or rubber and can be bought at any toy store for a small sum. The cups should be about 4" in diameter and the center of each cup should be 6¼ inches from the center of the block A. The vertical spindle, C, of this instrument consists of an unbrella rib about 12 inches long, which rests, at the bottom, on a piece of glass, D, so as to reduce friction. It is held in place against a wooden upright, E, by means of two small screw-eyes, F. At the bottom of the spindle is a small wooden disk, G, with a headless wire nail projecting from one side. Another disk, H, of slightly larger diameter is mounted to turn on the base which supports the instrument, and this has in its upper face nine small wire nails. Every time the anemometer makes a complete turn the pin of the disk G will turn the disk H the distance of one nail, so that it will take nine turns of the first disk to make the second disk complete one revolution.

If the instrument is properly constructed the number of revolutions of the larger disk in a minute will correspond approximately to the number of miles per hour that the wind is blowing. About 540 revolutions of the cups will measure a mile of wind.

The number of revolutions can be counted, if a watch is not at hand, by learning to count seconds. Usually we



FIGS. 226 TO 229.—The electric anemometer

think of a second as a very short interval of time. It is much longer than most people imagine it to be. The best way to count seconds is to say "one-half and one, one-half and two, one-half and three," and so on at a conversational rate, up to 60 which will be one minute. A little practice with a watch to check up the speed will teach us to count seconds very readily.

We can improve on this anemometer by using an electric contact device in connection with the larger disk, running down to an electromagnet inside our shack. The ane-

mometer must, of course, be placed in an exposed place where it will get the full sweep of the wind. The electrical contact spring, however, should be covered by some sort of housing, such as a tin box to keep out the rain. For our electric contact we shall need a spring strip, J, similar to that used in the weathervane but of very flexible brass. Instead of having long contact sectors, all we need is two brass-headed nails, K, over which the contact strip will pass at each revolution of the larger counting disk. Wires from these nails run down into the shack, as indicated on the diagram, Fig. 227, where one of them is connected with one pole of an electromagnet, L, while the other runs to a pole of the battery. A wire from the other pole of the battery runs through a contact button and thence to the other pole of the electromagnet. This magnet should be a more elaborate affair than the magnets used in our weathervane, because it is intended to operate an armature. It may be made of a bundle of soft iron wire bent to a U-shape and on each arm of the U a coil of wire must be mounted. Each coil should consist of about half an ounce of No. 20 single cotton-covered magnet wire, and care must be taken to have the turns of wire in one coil connected with the turns of wire in the other so that the coils will run in the same direction upon each arm. This is shown diagrammatically in Fig. 228.

With the armature all we need is a large wire nail, M. The head of the nail should be filed at each side so as to form pivot points, as shown in Fig. 229. The points pivot between two blocks, N, and the point of the nail rests on a block, O. The magnet, L, is set very close to the nail, so

that when a current passes through the magnet the nail will be lifted up coming with a click against the magnet. As soon as the current is broken, of course, the nail will drop back to its seat. Thus, while the button is pressed and the anemometer is spinning around, at each revolution of the larger wheel there will be a click, and counting the number of these clicks in a minute we shall know just how fast the wind is traveling.

Rain Gauge

Our third weather instrument is a rain gauge, which may be made very simply out of a long, narrow bottle, a funnel and a tin can. The diameter of the tin can ought to be at least twice as large as the diameter of the bottle.

First we must get the measure of the bottle. Fill the can with water until it is just 1 inch deep, then pour this into the bottle, and with a sharp file scratch a mark on the glass to indicate the depth of the water. Then pour in another inch of water as measured in the can and mark the depth on the bottle. The space between the first and second mark can be divided off into quarters by means of a ruler. But we cannot do this with the first inch because the bottom of the bottle is apt to be irregular and we shall have a greater depth here than in the second inch. So we shall have to carefully measure off 1/4 inch, 1/2 inch and 3/4 inch in our tin can and pour it into the bottle. The can should be so large that a depth of 2 inches in it would fill the bottle almost to the neck. It is seldom that we have to measure more than 2 inches in a single rainstorm. Now by heating the can over a gas jet or over the burner of a gas stove,

we can melt off the bottom and we shall have a collar, A, that is to be fitted into a hole in a board, B, Fig. 230. This collar may be secured by means of a tack or two nailed through the tin into the opening of the board. The collar should be at least 2 inches deep and should project from the upper face of the board. To the under side of the board, directly under the collar, a large funnel, C, is secured

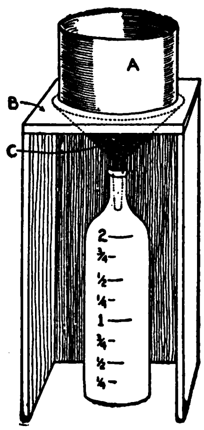


FIG. 230—The rain gauge

by means of tacks whose heads overlap the rim of the funnel.

The board, B, may form the top of a box with one side open which will be long enough to receive the bottle as shown.

This instrument set out in the rain will get all the water that falls into the collar, and we can measure the amount of rain that has fallen by noting the depth of the water in the bottle. Usually a rainfall amounts to a very small

figure in depth of inches, and if we attempted merely to measure the depth of water in a can we should be liable to considerable error, but when this water is collected in a bottle of much smaller cross-section than the opening into which the rain falls, the depth of water is much greater and accordingly it is easier to measure it.

The Sunshine Recorder

There is another instrument which the Weather Bureau suggests that boys can make, and this is a photographic sunshine recorder. The directions are as follows: Take a large tin can about 5 or 6 inches in diameter and with a good cover. Divide it into halves by a pasteboard partition, A (Fig. 231), running lengthwise of the can. One half will serve for the morning record and the other half for the afternoon. Punch a hole in each half of the can and then take two pieces of blueprint paper, C, and fit them in the can curving them to the arc of a circle with the pinhole as the center. This can should be set up on a block of wood so that the axis of the can points toward the North Star. Then the sun, in passing over the can, will shine, in the morning hours, through one pinhole, and in the afternoon hours through the other. The ray of light will make a photographic record, X, on the blueprint paper. Whenever the light is cut off by clouds the line traced on the blueprint paper will be faded. It is not necessary to use a new sheet of paper for each day. The paper may be slipped upward a little each morning or evening. After the record is completed, the blueprint is merely washed in water, when the lines will appear. To show time, the pinhole should be

covered for a few minutes at the beginning of each hour of one day. This will form hour lines on the record which will be the same for all the other sheets of blueprint paper.

There is one more device which it will be interesting to make in connection with our Weather Bureau, and that is an apparatus for filling small balloons with gas. Small spherical balloons are used by artillery men to determine the direction of the wind far up in the sky. These small gas-filled balloons float up rapidly and drift with the wind; then

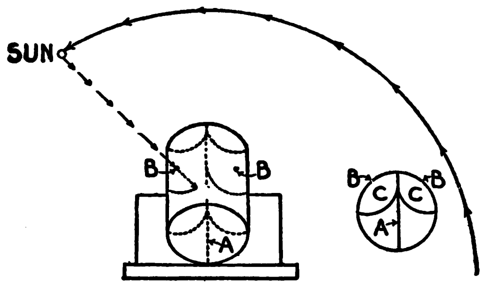


FIG. 231.—The sunshine recorder

instruments are trained on them to determine the direction and the rate of the drift. While we shall not have any such excuse for making sounding balloons, nevertheless it will be interesting to see which way the wind is blowing far above us.

It is not a very difficult matter to fill an ordinary toy balloon with illuminating gas so that it will actually float. To do this we shall need a large bottle with a big cork stopper in it. Through this stopper three holes must be punched. It will be easier to use a wooden stopper instead of a cork one, as it is rather difficult to cut clean holes in

cork. The wooden stopper can then be rendered gas-tight after it has been inserted in the bottle by pouring paraffine wax over it. We shall need glass tubing long enough to reach the bottom of the bottle, and also two other short pieces one of which is to be connected with the balloon and the other by means of rubber tubing to the gas jet. The long

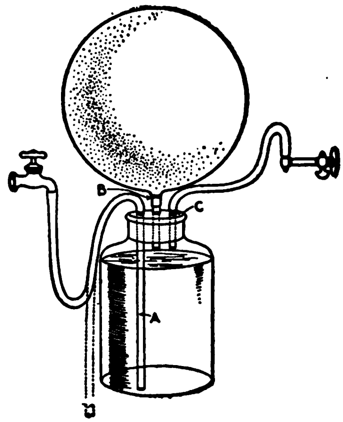


FIG. 232.—Filling a balloon with gas

tube, A, Fig. 232, is connected by a piece of rubber hose to a faucet and water is turned on until the jar is filled.

The balloon is deflated; that is, it is squeezed to force out all the air in it, and then is attached to the central tube, B, by means of a rubber band. The water in the jar should not be quite high enough to reach the balloon tube or the gas tube, C, so that when the gas is turned on it will flow into the balloon and fill it without carrying water in. The pressure of the gas is seldom enough to inflate a balloon sufficiently without help. It is for this reason that we use

the water-filled jar. The water is introduced into the jar before the filling of the balloon so as to drive out practically all the air in the jar.

After the balloon has been filled with gas the water is drawn out of the jar by disconnecting the tube from the faucet and letting it hang down below the bottom of the jar. If the gas pressure is not sufficient to force the water out, it may be started running by sucking on the end of the tube. It will then keep on running out until the bottle is almost empty, while at the same time the gas is pouring in. Before the water uncovers the lower end of the water tube, A, the gas should be turned off and the tube A should be connected with the faucet. Then on turning on the faucet gently, water will flow into the jar forcing the gas, that is in there, up into the balloon. When the balloon has been sufficient inflated, the faucet is turned off and the balloon is sealed just above its tube by means of a rubber band.

If the stopper of the jar is tight and all the connections to the gas jet and the faucet are carefully made, there should be no difficulty at all in filling a small sounding balloon with gas at sufficient pressure to distend it very nicely. It will then be light enough to rise high into the air.

With all these instruments and devices for gauging weather conditions, we shall find the study of meteorology very fascinating and should be able to predict immediate weather conditions as well as a mariner, and weather wisdom will be most useful to the boy who loves outdoor work and play.

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